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Human Factors Guidelines for the Evaluation of Airborne Data Link

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Albert Rehmann

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16. Abstract

The purpose of this document is to provide human factors specialists and certification authorities with a consolidated set of tailored guidelines that can be employed to evaluate the designs of actual or proposed airborne Data Link systems. The guidelines deal with the human factors aspects of the pilot's interface, particularly those affecting the design of the computer software, and display/control hardware comprising such systems.

The guidelines were compiled from a number of recognized sources that have been successfully employed by human factors practitioners to design and assess computer-human interfaces in recent years. Guidelines for interface software were derived primarily from those developed by Smith and Mosier (1986). Guidelines for the physical design of display/control hardware were obtained, to a large extent, from MIL-STD-1472D (1989), which is often cited in government procurement contracts.

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1. INTRODUCTION.

The purpose of this document is to provide human factors specialists, and certification authorities, with a consolidated set of tailored guidelines that can be employed to evaluate the designs of actual or proposed airborne Data Link systems. The guidelines deal with the human factors aspects of the pilot's interface, particularly those affecting the design of the computer software and display/control hardware comprising such systems.

The guidelines were compiled from a number of recognized sources that have been successfully employed by human factors practioners to design and assess computer-human interfaces (CHI) in recent years. Guidelines for interface software were derived primarily from those developed by Smith and Mosier (1986). Guidelines for the physical design of display/control hardware were obtained, to a large extent, from MIL-STD-1472D (1989), which is often cited in government procurement contracts.

1.1 BACKGROUND.

The pilot's interface must be well designed from a human factors viewpoint to ensure efficient, error-free system performance. Techniques for message entry and retrieval, for example, must be carefully selected and implemented to minimize pilot workload, memory demand, and "head-down" time, in cockpits. A poorly-designed interface places excessive demands on the pilot, and reduces the time available to perform other primary flight tasks. The potentially hazardous effects of a poor design become particularly apparent during periods of high workload and stress, where the pilot's information processing capability is taxed to its limit.

At the present time, there is no single source of guidance that system developers and certification authorities can employ to assess the adequacy of various interface designs. What guidance does exist is also very general in nature, and requires tailoring before it can be applied to a specific system. Yet, at the present time, Data Link systems do exist, and are being successfully used by air carriers to exchange company messages. New systems are also under development to provide both tactical and strategic air traffic control (ATC) services (e.g., clearances, position reports, and altitude and route changes). Due to the nature of these services and potentially hazardous effects of human error, system developers and certification authorities are seeking guidance from the human factors community which can be used to assess the adequacy of interface designs, even though it may be somewhat imprecise and difficult to apply, particularly in the area of interface software design. In spite of this short coming, some guidance is better than none. This

report contains the results of an initial effort to provide such guidance.

The guidelines, contained herein, were selected and tailored as much as possible for application to airborne Data Link systems. Guidelines for interface software are, by necessity, still somewhat general in nature, and perhaps can only be applied by an experienced human factors specialists who is familiar with Data Link systems.

1.2 ORGANIZATION OF GUIDELINES.

The guidelines are organized into three broad categories. Section 2 deals with general guidelines that should be treated as objectives or goals to be achieved in the interface design. Section 3 contains guidelines that pertain to the CHI software. These require some interpretation before they can be applied to some areas of design. For this reason, the guideline user is referred to applicable sections of Smith and Mosier (1986), where examples and comments are offered by the authors to clarify some of the more allusive guidelines. Human factors specialists may also be consulted to gain a thorough understanding of the guidelines, and their application to specific designs. Section 4 is devoted to guidelines that deal with the physical design of control/display hardware. These guidelines are more definitive and quantitive in nature, requiring relatively little interpretation or special knowledge for their application.

1.3 APPLICATION OF GUIDELINES.

As previously mentioned, the guidelines may be used during the development of new Data Link systems, once translated into specific design requirements. They may also be used to evaluate existing systems, including those still in the design stage, provided their interfaces are defined in sufficient detail to permit evaluation. Regardless of the system's maturity, the design evaluator must have a thorough understanding of Data Link services being supported by the system, and the messages exchanged between the aircraft and ground. The evaluator must also know how the system is designed to operate, and how system functions are allocated between the pilot and computer. Knowing what functions the pilot is expected to perform in each service, the evaluator will be able to assess the adequacy of the information provided, as well as methods used for its presentation. With this knowledge, the guidelines can be tailored for application to a particular system's interface design.

Obviously, not all guidelines proposed here can or should be applied to any single system. Many of them are not applicable, since the system, for example, may not make use of "form filling" as a data entry technique, but some other technique suitable for

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the task being performed. The system also may not contain a Cathode-Ray Tube (CRT) display, but some other type, such as a dot matrix display with a touch panel. Hence, the guidelines will also need to be tailored to eliminate non- applicable guidelines. Hence, the evaluator should first select the appropriate guidelines and prepare them in the form of a checklist, and general guidelines be rewritten in a form more specific to the system under evaluation.

Application of the checklist is best carried out working in collaboration with pilots who have actually used the system, or have been intimately involved in its design. Their (users) comments and opinions should also be solicited and presented, together with the assessment results. Each item in the checklist should be treated as a requirement, and the interface examined to determine its level of compliance.

It should be emphasized, at this point, that no single deficiency in the interface design will necessarily result in poor performance or system failure. Pilots have shown an uncanny ability to compensate for such deficiencies with a little extra effort. However, there is a limit to how well pilots can adapt to a poorly designed interface. Design deficiencies have a habit of accumulating to a point where they can cause, not only degraded, but also hazardous, performance. The hazardous effects of this accumulation process become more apparent during periods of high workload and stress. This suggests that a good interface design contains *few, if any, design flaws requiring pilot adaptation.*

Examination of the proposed guidelines also reveals that certain items are more critical than others in terms of their potential for producing error if not complied with. For example, using an inappropriate abbreviation on a pushbutton to identify its function is less critical than not providing an appropriate data entry technique. Hence, the guidelines should also be prioritized in terms of their potential for producing error.

In view of the above discussions, it is recommended that each of the selected checklist items be weighted using a simple scale of one to five, with five indicating the highest level of criticality. Once the checklist is applied to a particular interface design, an overall compliance score, or figure-of-merit, can be calculated. Simply take the sum of the weighted scores and express it as a percentage of the maximum possible score. The relative merits of various interface designs can then be compared on a guantative and consistent basis.

2. GENERAL GUIDELINES.

2.1 OBJECTIVES.

The design of airborne Data Link systems must foster effective procedures, work patterns and safety, and minimize factors which degrade human performance or increase error. The design must also be such that aircrew workload, accuracy, time constraint, mental processing, and communication requirements do not exceed human capabilities. In addition, the design should minimize training requirements within the limits of time, cost, and performance trade-offs.

2.2 FUNCTION ALLOCATION.

The design should reflect allocation of functions to aircrew, equipment, and aircrew/equipment combinations to achieve:

    a. Required sensitivity, precision, speed, and safety.

    b. Required reliability of system performance.

    c. Minimum level of skills required to operate and maintain the system.

2.3 SIMPLICITY OF FORM.

The system, including both hardware and software, would represent the simplest design consistent with functional requirements and expected service conditions. It should be capable of being operated, maintained, and repaired in its operational environment by personnel with a minimum of training.

2.4 SAFETY.

The design must reflect applicable system and personnel safety factors. Minimization of potential human error in the operation and maintenance of the system, particularly under the conditions of alert, stress, or other emergency or non-routine conditions is an example.

3. CHI.

3.1 GENERAL GUIDELINES.

Computer programs and equipment interfaces will provide a functional interface between the system for which they are designed, and users (operators/maintainers) of that system. This interface must optimize compatibility with personnel, and minimize conditions that could degrade human performance or contribute to human error.

3.1.1 Standard Procedures.

Pilots should be provided standard procedures for similar, logically-related transactions.

3.1.2 Computer Response.

Every input by a pilot should consistently produce some perceptible response output from the computer.

3.1.3 On-Line Guidance.

Pilots should be provided on-line data and message indices, and dictionaries, to guide selection and composition for data and message entries. Definitions of allowable options, system capabilities, procedures, and ranges of values shall be displayable at the pilot's request.

3.1.4 System Status.

Pilots should be provided information on system status at all times, regarding operational modes, availability, and loads, either automatically or by request.

3.2 DATA ENTRY.

3.2.1 General.

Data entry functions should be designed to establish consistency of data entry transactions, minimize input actions and memory load on the user, ensure compatibility of data entry with data display, and provide flexibility of user control of data entry.

3.2.1.1 User Pacing-Manual.

Data entry should be paced by the user, rather than by the system.

3.2.1.2 Positive Feedback.

The system should provide a positive feedback (e.g., tactile, visual, and auditory) to the user of the acceptance or rejection of a data entry.

3.2.1.3 Processing Delay.

Where system overload or other system conditions will result in a processing delay, the system should acknowledge the data entry, and provide an indication of the delay to the user. If possible, the system shall advise the user of the time remaining for the process, or of the fraction of the process completed.

3.2.1.4 Explicit Action.

Data entry should require an explicit completion action, such as the depression of an ENTER key.

3.2.1.5 Validation.

Data entries should be validated by the system for correct format, legal value, or range of values. Where repetitive entry of data sets is required, data validation for each set should be completed before another transaction can begin.

3.2.1.6 Software-Available Data.

The pilot should not be required to enter data already available to the software.

3.2.1.7 Input Units.

Data should be entered in units which are familiar to the pilot.

3.2.1.8 Cursors.

3.2.1.8.1 Control.

Systems employing cursors should provide cursor-control capability. The user should be able to adjust the sensitivity of the cursor movement to be compatible with the required task and user skills.

3.2.1.8.2 Display.

A movable cursor within the display should have a distinctive visual attribute that does not obscure other displayed entities. The cursor should not move beyond the display boundaries and disappear from sight. If the cursor is moved by depressing a key, releasing the key shall cause the cursor to stop moving.

3.2.1.8.3 Home Position.

The home position for the cursor should be consistent across similar types of displays.

3.2.1.8.4 Explicit Actuation.

A separate, explicit action, distinct from cursor position, should be required for the actual entry (e.g., enabling, actuation) of a designated position.

3.2.1.8.5 Consistent Positioning.

Where cursor positioning is incremental by discrete steps, the step size of cursor movement should be consistent horizontally (i.e., in both right and left directions), and vertically (in both up and down directions).

3.2.1.8.6 Keyboard Cursor Control.

When position designation is required in a task emphasizing keyed data entry, cursor control should be done by some device integral to the keyboard. If cursor movement is accomplished by depressing keys, the keys should be located on the main keyboard.

3.2.1.8.7 Movement Relationships.

The response of a cursor to control movements should be consistent, predictable, and compatible with the user's expectations. For cursor control by key action, a key labeled with a left-pointing arrow should move the cursor leftward on the display; for cursor control by joystick, leftward movement of the control should result in leftward movement of the cursor.

3.2.1.9 Abbreviations, Mnemonics, and Codes.

When abbreviations, mnemonics, or codes are used to shorten data entry, they should be distinctive, and have a relationship or association to normal language or specific job-related terminology. Abbreviations should be the same length, the shortest possible that will ensure unique abbreviations.

3.2.1.10 Explicit Delete Action.

Data deletion or cancellation should require an explicit action, such as the depression of a DELETE key.

3.2.1.11 Change of Data.

Where a user requests change (or deletion) of a data item that is not currently being displayed, the option of displaying the old value before confirming the change should be presented.

3.2.1.12 Single Method of Data Entry.

Data entry methods and data displays should not require the user to shift between entry methods.

3.2.1.13 Data Entry Display.

Where data entry on an electronic display is permitted only in prescribed areas, a clear visual definition of the entry fields should be provided.

3.2.2 Keyboard.

3.2.2.1 Use.

A keyboard should be used to enter alphabetic, numeric and other special characters into the system.

3.2.2.2 Configuration.

Keyboards frequently used to enter text messages should conform to MIL-STD-1280 (see figure 3.2.2.2-1) unless otherwise specified or approved by the procuring activity.

3.2.2.3 Timely Display.

Keyed inputs, except security items such as passwords, should be shown on the display in accordance with the values in table 3.2.2.3-1.

3.2.2.4 Length.

The length of individual data items should be minimized.

3.2.2.5 Numeric Keypads.

Keyboards used in systems requiring substantial numeric input should be equipped with a numeric keypad.

3.2.2.6 Minimization of Keying.

The amount of keying required should be minimized.

3.2.2.7 Minimization of Shift Keying.

The use of key-shifting functions should be minimized during data entry transactions.

3.2.2.8 Data Change.

In keyed data entry, means should be provided to allow users to change previous entries, if necessary, by DELETE and INSERT actions.

3.2.3 Fixed Function (Dedicated) Keys.

3.2.3.1 Use.

Fixed-function keys (for example, ENTER) should be used for time-critical, error-critical, or frequently-used control inputs.
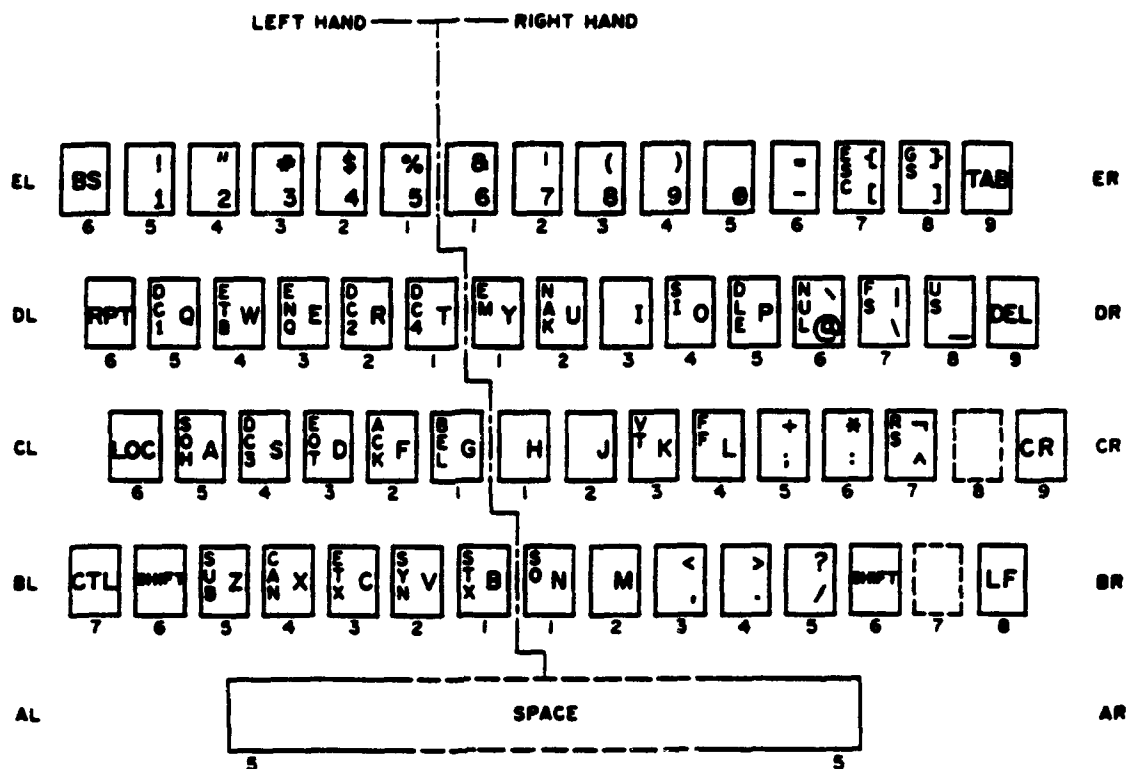
NOTES

1. PHYSICAL CHARACTERISTICS AND LOCATIONS (i.e. SIZE, SHAPE, SKEW, ETC) OF SPACE BAR OR KEYS ARE NOT TO BE INFERRED

2. ARRANGEMENT TYPE I, CLASS I AS PER MIL-STD-1280

FIGURE 3.2.2.2-1.   TYPE I, CLASS 1 STANDARD KEYBOARD ARRANGEMENT

TABLE 3.2.2.3-1 DIALOGUE TYPE VERSUS
USER TRAINING AND SYSTEM RESPONSE

Dialogue Type	Required User Training	Tolerable Speed of System Response
Question and Answer	None	Moderate (0.5 to less than 2 seconds (secs))
Menu Selection*	None	Very Fast (less than 0.2 secs)
Form Filling*	Moderate	Slow (greater than 2 secs)
Function Keys*	Moderate	Very Fast (less than 0.2 secs)
Command Language	High	Moderate/Slow (0.5 to greater than 2 secs)
Natural/Query Language	Moderate	Fast (0.2 to less than 0.5 sec)
Graphic Interaction*	High	Very Fast (less than 0.2 sec)

*NOTE: Considered most suited to Airborne Data Link (ADL) Systems.

3.2.3.2 Standardization.

Fixed-function keys should be common throughout the system.

3.2.3.3 Functional Consistency.

Once a key has been assigned a given function, it should not be reassigned to a different function for a given user.

3.2.3.4 Availability.

Fixed-function keys should be selected to control functions that are continuously available, i.e., lockout of fixed-function keys shall be minimized. At any step in a transaction sequence, however, function keys which are not used for current inputs should be temporarily disabled under computer control. Mechanical overlays should not be used for this purpose.

3.2.3.5 Non-Active Keys.

Non-active fixed-function keys should be replaced by a blank key on the keyboard.

3.2.3.6 Grouping.

Fixed-function keys should be logically grouped, and shall be placed in distinctive locations on the keyboard.

3.2.3.7 Actuation.

Except when used to toggle between two opposing states, a fixed-function key should require only a single actuation to accomplish its function.

3.2.3.8 Feedback.

When fixed-function key activation does not result in an immediately-observable natural response, the user should be given indication of system acknowledgement.

3.2.3.9 Function Labels.

Key assignments should be displayed at all times, preferably through direct marking. Where abbreviations are necessary, standardized abbreviations (e.g., MIL-STD-12, MIL-STD-411, MIL-STD-783) should be used.

3.2.4 Variable Function Keys.

3.2.4.1 Use.

Variable function keys may be used for programmable menu selection, and entry of control functions.

3.2.4.2 Status Display.

When the effect of a function key varies, the status of the key should be displayed.

3.2.4.3 Reprogrammable or Inactive Default Function.

When keys with labeled default functions are reprogrammed or turned off, a visual warning should alert the user that the standard function is not currently accessible via that key.

3.2.4.4 Relabeling.

Provisions should be made for easily relabeling variable function keys. Labels for variable function keys, located along the perimeter of a display, may be generated on th display face.

3.2.4.5 Shifted Characters.

Shift keys should not be required to operate variable function keys.

3.2.4.6 Easy Return to Base-Level Functions.

Where the functions assigned to a set of function keys change as a result of user selection, the user should be given an easy means to return to the initial, base-level functions. For example, in cockpit design, where multifunction keys may be used for various purposes such as navigation, the aircrew should be able to take a single action to restore those keys quickly to their basic flight control functions.

3.2.5 Touch Screen.

See paragraph 4.4.15 for information on touch screens.

3.3 DATA FORMAT.

3.3.1 Data Display.

3.3.1.1 Consistency.

Display formats should be consistent within a system as follows:

    a. When appropriate for users, the same format should be used for input and output.

    b. Data entry formats should match the source document formats where applicable.

    c. Essential data, text, and formats should be under computer, not user, control.

3.3.1.2 Criticality.

Only data essential to the user's needs should be displayed.

3.3.1.3 Readily Usable Form.

Data presented to the user should be in a readily usable and readable form such that the user does not have to transpose, compute, interpolate or mentally translate into other units, number bases or languages.

3.3.1.4 Order and Sequences.

When data fields have a naturally occurring order (e.g., chronological or sequential), such order should be reflected in the format organization of the fields.

3.3.1.4.1 Data Grouped by Importance.

Where some displayed data items are of significant importance or require immediate user response, those items should be grouped at the top of the display.

3.3.1.4.2 Data Grouped by Function.

Where sets of data are associated with particular questions, or related to particular functions, each set may be grouped to help illustrate those functional relationships.

3.3.1.4.3 Data Grouped by Frequency.

Where some data items are used more frequently than others, those items may be grouped at the top of the display.

3.3.1.5 Data Separation.

Separation of groups of information should be accomplished by blanks, spacing, lines, color coding, or other means consistent with the application.

3.3.1.6 Recurring Data Fields.

Recurring data fields within a system should have consistent names and should have consistent relative positions within displays.

3.3.1.7 Extended Alphanumerics.

When five or more alphanumeric characters without natural organization are displayed, the characters should be grouped in blocks of three to five characters within each group. If the characters are grouped, the groups shall be separated by a minimum of one blank space or other separating character, such as a hyphen or slash.

3.3.1.8 Labels and Titles.

Each display should be labeled with a title or label that is unique within the system. To make the display as meaningful as possible, and to reduce user memory requirements, every field or column heading should be labeled.

3.3.1.8.1 Display Title.

Every display should begin with a title or header at the top, describing briefly the contents or purpose of the display. There should be at least one blank line between the title and the body of the display.

3.3.1.8.2 Command Entry, Prompts, Messages at Bottom.

The last line(s) at the bottom of every display should be
reserved for status and error messages, prompts, and message
entry.

3.3.1.9 Data Group Labels.

Each individual data group or message shall contain a descriptive
title, phrase, word or similar device to designate the content of
the group or message. Labels should:

    a. Be located in a consistent fashion adjacent to (and
preferably above or to the left of) the data group or message
they describe.

    b. Be unambiguously related to the group, field, or message
they describe.

    c. Be highlighted or otherwise accentuated to facilitate
operator scanning and recognition.

    d. Be different, and easily distinguished from, that used to
highlight or code emergency or critical messages.

    e. Be unique and meaningful to distinguish them from data,
error messages, or other alphanumerics.

    f. Be displayed in upper case only, while text may be
displayed in upper and lower case.

    g. Reflect the question or decision being posed to the user,
when presenting a list of user options.

3.3.1.10 Scrolling.

Items continued on the next page (scrolled) should be numbered
relative to the last item on the previous page.

3.3.1.11 Page Numbering.

Each page of a multiple page display should be labeled to
identify the currently displayed page and the total number of
pages, e.g., Page 2 of 5.

3.3.1.12 Frame Identification.

Every display frame should have a unique identification to
provide a reference for use in requesting the display of that
frame. The frame identification should be an alphanumeric code

or an abbreviation which is prominently displayed in a consistent location. It should be short enough (3-7 characters) and/or meaningful enough to be learned and remembered easily.

3.3.2 Display Content.

3.3.2.1 Standardization.

The content of displays within a system should be presented in a consistent, standardized manner.

3.3.2.2 Information Density.

Information density shall be held to a minimum in displays used for critical task sequences. A minimum of one character space shall be left blank vertically above and below critical information with a minimum of two character spaces left blank horizontally before and after.

3.3.2.2.1 Crowded Displays.

When a display contains too much data for presentation in a single frame, the data should be partitioned into separately displayable pages.

3.3.2.2.2 Related Data on Same Page.

When partitioning displays into multiple pages, functionally related data items should be displayed together on one page.

3.3.2.2.3 Abbreviations and Acronyms.

Information shall be displayed in plain concise text whenever possible. Abbreviations and acronyms shall conform to MIL-STD-12, MIL-STD-411, or MIL-STD-783. New acronyms, if required, should be developed using the rules of abbreviation in MIL-STD-12. Abbreviations should be distinctive to avoid confusion. Words should have only one consistent abbreviation. No punctuation should be used in abbreviations. Definitions of all abbreviations, mnemonics and codes should be provided at the user's request.

3.3.2.3 Data Entry and Display Consistency.

Data display word choice, format, and style should be consistent with the requirements for data entry and control.

3.3.2.4 Context for Displayed Data.

The user should not have to rely on memory to interpret new data; each data display should provide needed context, including recapitulating prior data from prior displays, as necessary.

3.3.3 Display Coding.

3.3.3.1 Use.

Coding should be employed to differentiate between items of information, and to call the user's attention to changes in the state of the system. Coding should be used for critical information, unusual values, changed items, items to be changed, high priority messages, special areas of the display, errors in entry, and criticality of message entry. Consistent, meaningful codes should be used. Coding should not reduce legibility or increase transmission time.

3.3.3.2 Flash.

Flash coding should be employed to call the user's attention to critical events only. No more than two flash rates should be used. Where one rate is used, the rate should be between three and five flashes-per-second (s). Where two rates are used, the second rate should be less than two per s.

3.3.3.3 Brightness.

Brightness intensity coding should be employed only to differentiate between an item of information and adjacent information. No more than two levels of brightness should be used. Each level should be separated from the nearest by at least a 2:1 ratio.

3.3.3.4 Pattern and Location.

Pattern and location coding may be employed to reduce user search time by restricting the area to be searched to prescribed segments.

3.3.3.5 Underlining.

Underlining may be employed to indicate unusual values, errors in entry, changed items, or items to be changed.

3.3.3.6 Symbol and Size.

Symbol coding may be employed to enhance information assimilation from data and displays. Symbols should be analogs of the event of system element they represent, or be in general use and well known to the expected users. Where size difference between symbols is employed, the major dimensions of the larger should be at least 150 percent of the major dimension of the smaller, with a maximum of three size levels permitted.

3.3.3.6.1 Special Symbols.

When special symbols are used to signal critical conditions, they should be used for only that purpose.

3.3.3.6.2 Markers Close to Words Marked.

When a special symbol is used to mark a word, the symbol should be separated from the beginning of the word by one space.

3.3.3.7 Color.

Color coding may be employed to differentiate between classes of information in complex, dense, or critical displays. The colors selected should not conflict with associations of common color conventions (e.g., red to indicate danger). Information should not be coded solely by color, if the data must also be accessed from printed hardcopy versions.

3.3.3.8 Shape.

Shape coding may be used for search and identification tasks. When shape coding is used, the codes selected should be based on established standards or conventional meanings.

3.3.3.9 Brightness Inversion.

When a capability for brightness inversion is available (e.g., reverse video, where dark characters on a bright background can be changed to bright on dark, or vice versa), it may be used for highlighting critical items that require user attention. When used for alerting purposes, brightness inversion should be reserved consistently for that purpose, and not used for general highlighting.

3.3.4 Audio Displays.

3.3.4.1 Uses.

Audio displays (signals) used as part of the CHI have application where:

a. The common mode of visual display is restricted by overburdening or user mobility needs, and it is desirable to cue, alert or warn the user.

b. The user should be provided feedback after control actuation, data entry, or completion of timing cycles and sequences.

3.3.4.2 Other Requirements.

Other audio design criteria apply (see section 4.3).

3.3.4.3 Supportive Function - Audio.

Audio signals, used in conjunction with visual displays, should be supplementary to the visual signals, and used to alert and direct the user's attention to the appropriate visual display.

3.4 INTERACTIVE CONTROL.

3.4.1 General.

General design objectives include consistency of control action, minimized need for control actions, and minimized memory load on the user, with flexibility of interactive control to adapt to different user needs. As a general principle, it is the user who should decide what needs doing and when to do it. The selection of dialogue types should be based on anticipated task requirements and user skills. Different types of dialogue imply differences in system response time for effective operation. Estimated relative requirements for user training and for system response time are given in section 3.9.

3.4.1.1 Response Time.

System response time should be consistent with operational requirements. Required user response times should be compatible with required system response time. Required user response times should be within the limits imposed by total user tasking expected in the operational environment.

3.4.1.2 Simplicity.

Control/display relationships should be straightforward and explicit. Control actions should be simple and direct, whereas potentially destructive control actions should require extended user attention, so that they are not easily acted on.

3.4.1.3 Accidental Actuation.

Provision should be made to prevent accidental actuation of potentially destructive control actions, such as accidental erasure or memory dump.

3.4.1.4 Compatibility with User Skill.

Controls should be compatible with the lowest anticipated user skill levels. Experienced users should have options which shortcut intervening steps necessary for inexperienced users.

3.4.1.5 Availability of Information.

Information necessary to select or enter a specific control action should be available to the user, when selection of that control action is appropriate.

3.4.1.6 Concurrent Display.

Control actions to be selected from a discrete set of alternatives should have those alternatives displayed prior to the time of selection.

3.4.1.7 Hierarchial Process.

When hierarchical levels are used to control a process or sequence, the number of levels should be minimized. Display and input formats should be similar within levels, and the system should indicate the current positions within the sequence at all times.

3.4.1.8 User Memorization.

The requirement to learn mnemonics, codes, special or long sequences, or special instructions should be minimized.

3.4.1.9 Dialogue Type.

The choice of dialogue type (e.g., form filling, menus) for interactive control should be compatible with user characteristics and task requirements.

3.4.1.10 Number System.

When numeric data is displayed or required for control input, such data should be in the decimal, rather than binary, octal, hexadecimal or other number system.

3.4.1.11 Data Manipulation.

The user should be able to manipulate data without concern for internal storage and retrieval mechanisms of the system.

3.4.1.12 Computer Processing Constraints.

The sequence of transaction selection should generally be dictated by user choices, and not by internal computer processing constraints.

3.4.1.13 Feedback for Correct Input.

Control feedback responses to correct user input should consist of changes in state or value of those elements of the displays

which are being controlled in an expected and logically natural form. An acknowledgement message should be employed only in those cases where the more conventional mechanism is not appropriate, or where feedback response time must exceed one s.

3.4.1.14 Feedback for Erroneous Input.

Where control input errors are detected by the system (see section 3.8.2), error messages should be available as provided in section 3.8.5, and error recovery procedures should be as provided in section 3.8.8.

3.4.1.15 Control Input Data Display.

The presence and location of control input data entered by the user shall be clearly and appropriately indicated. The data displayed should not mislead the user with regard to nomenclature, units of measure, sequence of task steps, or time phasing.

3.4.2 Menu Selection.

3.4.2.1 Use.

Menu selection interactive control should be used for tasks that involve little or no entry of arbitrary data, and where users may have relatively little training. It should also be used when a command set is so large that users are not likely to be able to commit all of the commands to memory.

3.4.2.2 Devices.

Pointing devices, including touch technology, should be used for menu selection. Where design constraints do not permit pointing devices, a standard window should be provided for the user to key the selected option code. If menu selection is accomplished by pointing, dual actions should be provided. The first action should designate the selected option, followed by a separate action to enter the selection into the computer program.

3.4.2.3 Titles.

Each page of options (menu) should have a title that clearly describes the purpose of that menu.

3.4.2.4 Series Entry.

Users should be provided the capability to stack menu selections, i.e., to make several menu selections without having each menu displayed.

3.4.2.5 Sequences.

A menu should not consist of a long list of multi-page options, but should be logically segmented to allow several sequential selections among a few alternatives.

3.4.2.6 Active Option Presentation.

The system should present only menu selections for actions which are currently available.

3.4.2.7 Format Consistency.

Menus should be presented in a consistent format throughout the system, and should be readily available at all times.

3.4.2.8 Option Sequence.

Menu selection should be listed in a logical order, or, if no logical order exists, in the order of frequency of use.

3.4.2.9 Simple Menus.

When the number of selections can fit on one page in no more than two columns, a simple menu should be used. If the selection options exceed two columns, hierarchical menus may be used.

3.4.2.10 Option Presentation.

Selection codes and associated descriptors should be presented on single lines.

3.4.2.11 Direct Function Call.

If several levels of hierarchical menus are provided, a direct function call capability should be provided, so that the experienced user does not have to step through multiple menu levels.

3.4.2.12 Option Coding.

When selections are indicated by coded entry, the code associated with each option should be included on the display, in some consistent manner.

3.4.2.13 Keyed Codes.

If menu selections must be made by keyed codes, the options should be coded by the first several letters of their displayed labels, rather than by more arbitrary numeric codes. In defining the codes, however, they should not duplicate any other user function codes.

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3.4.2.14 Position in Structure.

When menu traversal can be accomplished by clearly defined hierarchical paths, the user should be given some indication of the displayed menu's current position in the overall or relevant structure, such as by having an optional display of "path" information. A menu tree showing the menu hierarchy should be included in the user manual.

3.4.2.15 Back Menu.

When using hierarchical menus, the user should be able to return to the next higher level by using single key action until the initial, top-level menu or display is reached.

3.4.2.16 Return to Top Level.

A function should be provided to directly recall the initial, top-level menu or display without stepping through the menu or display hierarchy.

3.4.3 Form Filling.

3.4.3.1 Uses.

Form-filling interactive control may be used where some flexibility in data to be entered is needed, and where the user will have moderate training. A form-filling dialogue should not be used when the computer must handle multiple types of forms, and the computer response is slow.

3.4.3.2 Grouping.

Displayed forms should be arranged so that related items are grouped together.

3.4.3.3 Format and Content Consistency.

The format and content of displayed forms should be perceptually related to that of paper forms, if paper forms are used to guide data entry. A standard input form should be used.

3.4.3.4 Distinctiveness of Fields.

Fields or groups of fields should be separated by spaces, lines, or other delineation cues. Required fields should be distinguished from optional fields.

3.4.3.5 Field Labels.

Field labels should be distinctively presented so that they can be distinguished from data entry. Labels for data entry field

should incorporate additional cueing of data format where the entry is made up of multiple inputs, e.g., DATE (M/D/Y): __/__/__ .

3.4.3.6 Cursor.

A displayed cursor should be positioned by the system at the first data entry field, when the form is displayed. The cursor shall be advanced by a tab key to the next data entry field, when the user has completed entry of the current field.

3.4.3.7 Entry Length Indication.

The maximum acceptable length for variable length fields should be indicated.

3.4.3.8 Overwriting.

Data entry by overwriting a set of characters in a field (such as a default) should not be used.

3.4.3.9 Unused Underscores.

When an item length is variable, the user should not have to remove unused underscores.

3.4.3.10 Dimensional Units.

When a consistent dimensional unit is used in a given entry field, the dimensional unit should be provided by the computer. When the dimensional unit varies for a given field it should be provided, or selected, by the user.

3.4.3.11 User Omissions.

When required data entries have not been input, the omissions should be indicated to the user, and either immediate or delayed input of the missing items should be allowed. For delayed entry, the user should be required to enter a special symbol in the field to indicate that the missing item is delayed, not overlooked.

3.4.3.12 Non-Entry Areas.

Non-entry (protected) areas of the display should be designated, and made inaccessible to the user via the cursor.

3.4.3.13 Flexible Data Entry.

When multiple data items are entered as a single transaction, the user should be allowed to re-enter, change, or cancel any item before taking a final ENTER action.

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3.4.3.14 Informative Labels.

Descriptive wording should be employed when labeling data fields; use of arbitrary codes should be avoided.

3.4.3.15 Logical Order.

Where no source document or external information is involved, forms should be designed so that data items are ordered in a logical sequence for input.

3.4.3.16 Form Filling for Control Entry.

Form filling should be considered as an aid for composing complex control entries. For example, for a print request, a displayed form might help a user invoke the various format controls that are available.

3.4.4 Fixed-Function Keys.

Fixed-function key interactive control may be used for tasks requiring only a limited number of control inputs, or in conjunction with other dialogue types.

3.4.5 Command Language.

3.4.5.1 Use.

Command language interactive control may be used for tasks involving a wide range of user inputs, and where user familiarity with the system can take advantage of the flexibility and speed of the control technique.

3.4.5.2 User Viewpoint.

A command language should reflect the user's point of view so that the commands are logically related to the user's conception of what is being done.

3.4.5.3 Distinctiveness.

Command names should be distinctive from one another.

3.4.5.4 Punctuation.

The command language should contain a minimum of punctuation or other special characters.

3.4.5.5 Abbreviations.

The user should be permitted to enter the full command name, or an abbreviation, for any command of more than five characters.

3.4.5.6 Standardization.

All commands and their abbreviations, if any, shall be standardized and consistent with MIL-STD-12, MIL-STD-411, or MIL-STD-783.

3.4.5.7 Displayed Location.

Commands should be entered and displayed in a standard location on the display.

3.4.5.8 Command Prompts.

The user should be able to request prompts, as necessary, to determine required parameters or available options for an appropriate next command entry.

3.4.5.9 Complexity.

The command language should be programmed in layers of complexity so that the basic layer will allow the inexperienced user to control a transaction. As this person's skill increases, the command language should allow skipping from basic to more advanced layers, to meet the user's current needs.

3.4.5.10 User Definition of Macro Commands.

The programming should not accept a user-designated macro name that is the same as an existing command name.

3.4.5.11 Standard Techniques for Command Editing.

Users should be allowed to edit erroneous command entries with the same techniques that are employed to edit data entries, since consistent editing techniques will speed learning and reduce errors.

3.4.5.12 Destructive Commands.

Where a command entry may have disruptive consequences, the user should be required to review and confirm a displayed interpretation of the command before it is executed.

3.4.6 Question and Answer.

3.4.6.1 Use.

Question-and-answer dialogues should be considered for routine data entry tasks where data items are known and their ordering can be constrained, where users will have little or no training, and where the computer is expected to have medium response speed.

3.4.6.2 Questions Displayed Separately.

Each question should be displayed separately in question-and-answer dialogue; users should not be required to answer several questions at once.

3.4.6.3 Recapitulating Prior Answers.

When a series of computer-posed questions are interrelated, answers to previous questions should be displayed when those will provide context to help a user answer the current question.

3.4.6.4 Source Document Capability.

When questions prompt entry of data from a source document, the question sequence should match the data sequence in the source document.

3.5 FEEDBACK.

3.5.1 Use.

Feedback should be provided that presents status information, confirmation, and verification throughout the interaction.

3.5.2 Stand-By.

When system functioning requires the user to stand-by, WORKING, BUSY, or WAIT messages should be displayed until user interaction is again possible. Where the delay is likely to exceed 15 s, the user should be informed. For delays exceeding 60 s, a count-down display should show delay time remaining.

3.5.3 Process Outcome.

When a control process or sequence is completed or aborted by the system, positive indication should be presented to the user concerning the outcome of the process, and the requirements for subsequent user action.

3.5.4 Input Confirmation.

Confirmation should not cause displayed data removal.

3.5.5 Current Modes.

When multiple modes of operation exist, a means should be provided to remind the user of the current mode.

3.5.6 Highlighted Option Selection.

When a displayed message or datum is selected as an option or input to the system, the subject items should be highlighted to indicate acknowledgment by the system.

3.5.7 User Input Rejection.

If the system rejects a user input, feedback should be provided to indicate the reason for rejection, and the required corrective action. Feedback should be self explanatory.

3.5.8 Feedback Message Content.

Users should not be required to translate feedback messages by use of reference system or code sheets, including error codes. Abbreviations should not be used, unless necessary.

3.5.9 Time-Consuming Processes.

The system should give warning information when a command is invoked which will be time consuming to process.

3.6 PROMPTS.

3.6.1 Use.

Prompts and help instructions should be used to explain commands, error messages, system capabilities, display formats, procedures and sequences, and to provide data. Prompting should conform to the following:

a. When operating in special modes, the system should display the mode designation.

b. Before processing any user requests which would result in extensive or final changes to existing data, the system should require user confirmation.

c. When missing data are detected, the system should prompt the user.

d. When data entries or changes will be nullified by an abort action, the user should be requested to confirm the abort.

e. Neither humor nor admonishment should be used in structuring messages; the dialogue should be strictly factual and informative for the user.

f. Error messages should appear as close as possible to the user entry that caused the message.

g. If a user repeats an entry error, the second error message should be revised to include a noticeable change, so that the user may be certain that the computer has processed the attempted correction.

3.6.2 Standard Display.

Prompting messages should be displayed in a standardized area of the display.

3.6.3 Prompt Clarity.

Prompts should be clear and understandable. They should not require reference to coding schemes or conventions which may be unfamiliar to the user.

3.6.4 Definitions.

A dictionary of abbreviations and codes should be available on-line. Definitions of allowable options and ranges of values should be displayable at the user's request.

3.6.5 Consistent Terminology.

On-line documentation, off-line documentation, and help instructions should use consistent terminology.

3.6.6 User Confirmation.

User acceptance of stored data or defaults should be possible by a single confirming keystroke.

3.7 DEFAULT.

3.7.1 Workload Reduction.

Default values should be used to reduce user workload. Currently defined default values should be displayed automatically in their appropriate data fields with the initiation of a data entry transaction, and the user should indicate acceptance of the default.

3.7.2 User Selection.

The user should have the option of generating default values based on operational experience, if the systems designer cannot predefine appropriate values.

3.7.3 Default Substitution.

The user should be able to replace any default value during a given transaction without changing the default definition.

3.7.4 Defaults for Sequential Entries.

Where a series of default values have been defined for a data entry sequence, the user should be allowed to default all entries, or to default until the next required entry. The experienced user may not wish to accept each default value for each data field individually.

3.8 ERROR MANAGEMENT/DATA PROTECTION.

3.8.1 Error Correction.

Where users are required to make entries into a system, an easy means should be provided for correcting erroneous entries. The system should permit correction of individual errors without requiring re-entry of correctly-entered commands or data elements.

3.8.2 Early Detection.

A capability should be provided to facilitate detection and correction of errors after keying in, but before entering into the system. While it is desirable that errors be detected early, error checking should occur at logical data entry breaks, e.g., at the end of data fields rather than character-by-character, in order to avoid disrupting the user.

3.8.3 Internal Software Checks.

User errors are minimized by use of internal software checks of user entries for validity of item, sequence of entry, completeness of entry, and range of value.

3.8.4 Critical Entries.

The system should require the user to acknowledge critical entries prior to their being implemented by the system. An explicitly labeled CONFIRM function key, different from the ENTER key, should be provided for user confirmation of control and data entries that have been questioned by the computer.

3.8.5 Error Message Content.

Error messages should be constructive and neutral in tone, avoiding phrases that suggest a judgment of the user's behavior. The error messages should reflect the user's view, not that of the programmer. Error messages should be appropriate to the user's level of training, be as specific as possible to the user's particular application, and describe a way to remedy, recover, or escape from the error situation (Use "DATA LINK LOST USE VOICE" instead of simply "DATA LINK LOST").

3.8.6 Diagnostic Information.

Error messages should explicitly provide as much diagnostic information and remedial direction as can be inferred reliably from the error condition. Where clear inference is not possible, probable helpful inference(s) may be offered.

3.8.7 Correction Entry and Confirmation.

When the user enters correction of an error, such corrections should be implemented by an explicit action by the user (e.g., actuation of an ENTER key.) All error corrections by the user should be acknowledged by the system, either by indicating a correct entry has been made or by another error message.

3.8.8 Spelling Errors.

Spelling and other common errors should not produce valid system commands or initiate transactions different from those intended. When possible, the systems shall recognize common misspellings of commands and execute the commands as if spelling has been correct. Computer-corrected commands, values, and spellings should be displayed and highlighted for user confirmation.

3.8.9 Errors in Stacked Commands.

To prompt for corrections of an error in stacked commands, the systems should display the stacked sequence with the error highlighted. Where possible, a procedure should be provided to correct the error, and salvage the stack.

3.8.10 Display of Erroneous Entries.

A computer-detected error, as well as the error message, should be continuously displayed until the error is corrected.

3.8.11 HELP.

In addition to explicit error management aids, (labels, prompts, advisory messages) and implicit aids (cueing), users should be able to obtain further on-line guidance by requesting HELP. Following the output of a simple error message, users should be permitted to request a more detailed discussion at levels of increasing detail, if possible.

3.8.11.1 Standard Action to Request HELP.

A simple, standard action that is always available should be provided to request HELP.

3.8.11.2 Multilevel HELP.

When an initial HELP display provides only summary information, more detailed explanations should be provided in response to repeated user requests for HELP.

3.8.11.3 Browsing HELP.

Users should be permitted to browse through on-line HELP displays, just as they would through a printed manual, to gain familiarity with system functions and operating procedures.

3.8.12 Data Security.

Data should be protected from unauthorized use, potential loss from equipment failure, and user errors.

3.8.12.1 Automated Security Measures.

Automated measures should be provided to minimize data loss.

3.8.12.2 User Identification.

User identification procedures should be as simple as possible, consistent with adequate data protection. For protection of a password, the password should not be echoed on the display. Audio, rather than visual feedback, should be provided when entering secure passwords during log-on.

3.8.12.3 Choice of Passwords.

If required, users should be allowed to choose their own passwords, since chosing their own will generally make it easier to remember.

3.8.12.4 Changing Passwords.

Users should be allowed to change passwords whenever they choose. All passwords should be changed at periodic intervals.

3.9 SYSTEM RESPONSES TIME.

Maximum system response time for real-time systems should not exceed the values of table 3.9-1. If computer response time will exceed 15 s, the user should be given a message indicating that the system is responding.

TABLE 3.9-1. SYSTEM RESPONSES TIMES

System Interpretation	Response Time Definition	Maximum Acceptable Response Time (Ss)
Key Response	Key depression until positive response; for example, "click"	0.1
Key Print	Key depression until appearance of character	0.2
Page Turn	End of request until first few lines are visible	1.0
Page Scan	End of results until text begins to scroll	0.5
XY Entry	From selection of field until visual response	0.2
Function	From selection of command until response	2.0
Pointing	From input of point to display point	0.2
Local Update	Change to image using local data bases; for example, new menu list from display buffer	0.5
Inquiry (Simple)	From command until display of a commonly used message	2.0
Error Feedback	From entry of input until error message appears	2.0

3.10 OTHER GUIDELINES.

3.10.1 Overlays.

Mechanical overlays, such as coverings over the keyboard, or transparent sheet placed on the display, should be avoided.

3.10.2 Hard Copy.

The user should have the capability to obtain a paper copy of the exact contents of the display in those systems where:

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a. Mass storage is restricted.
b. Mass stored data can be lost by power interruption.
c. Record keeping is required.

3.10.2.1 Display Print.

The user should be able to print a display by simple request, e.g., PRINT-SCREEN, without having to take a series of other actions first. Examples of unnecessary actions are: calling for the display to be filed, specifying a file name, then calling for a print of the named file.

3.11 DATA AND MESSAGE TRANSMISSION.

3.11.1 General.

3.11.1.1 Functional Integration.

Data transmission functions should be integrated with other information handling functions within a system.

3.11.1.2 Functional Wording.

Functional wording should be used for the terms used in data transfer, data transmission, and data reception. Functional wording should also be used for preparing and addressing messages, for initiating and controlling message transmission and other forms of data transfer, and for receiving messages, so that those terms will match users' work-oriented terminology.

3.11.1.3 Consistent Procedures.

Procedures for preparing, sending, and receiving messages should be consistent from one transaction to another, and consistent with procedures for other information-handling tasks.

3.11.1.4 Minimal Memory Load on User.

The data transmission procedures should be designed to minimize memory load on the user.

3.11.1.5 Minimal User Actions.

The data transmission procedures should be designed to minimize required user actions.

3.11.1.6 Flexible User Control.

Control of data transmission should be flexible so users can decide what data should be transmitted, when the data should be transmitted, and to where the data should be transmitted.

3.11.1.7 Interrupt.

User should be allowed to interrupt message preparation, review, or disposition, and then resume any of those tasks from the point of interruption.

3.11.1.8 Message Highlighting.

Software capabilities should be provided to annotate transmitted data with appropriate highlighting to emphasize alarm/alert conditions, priority indicators, or other significant second-order information that could affect message handling.

3.11.2 Preparing Messages.

3.11.2.1 Message Composition Compatible with Data Entry.

Procedures for composing messages should be compatible with general data entry procedures.

3.11.2.2 Stored Message Forms.

When message formats should conform to a defined standard or are predictable in other ways, prestored forms should be provided to aid users in message preparation.

3.11.2.3 Automatic Message Formatting.

When data must be transmitted in a particular format, as in data forms or formatted text, computer aids should be provided to generate the necessary format automatically.

3.11.2.4 Automatic Text Formatting.

When transmitted text must be formatted in a particular way, format control should be automatic with no extra attention required from the user.

3.11.2.5 Data Forms.

In preparing data forms for transmission, users should be allowed to enter, review, and change data on an organized display with field labels, rather than requiring users to deal with an unlabeled string of items.

3.11.2.6 Tables.

In preparing tabular data for transmission, users should be allowed to enter, review, and change data in customary formats, regardless of what the computer-imposed format will be for the actual transmission purposes.

3.11.2.7 Saving Draft Messages.

Users should be allowed to save draft messages during their preparation, or upon their completion.

3.11.3 Addressing Messages.

3.11.3.1 Destination Selection.

Users should be allowed to specify the destination(s) to which data will be transmitted.

3.11.3.2 Standard Address Header

For addressing and identifying messages, a basic set of header fields should be provided, so that all systems to which users will send messages can interpret them.

3.11.3.3 Prompting Address Entry.

When a user must specify the address for a message, prompting should be provided to guide the user in the process.

3.11.3.4 Address Directory.

Users should be provided with a directory showing address and radio frequencies for each destination.

3.11.3.5 Aids for Directory Search.

If possible, computer aids should be provided so a user can search an address directory by specifying a complete or partial name.

3.11.3.6 Extracting Directory Address.

Users should be allowed to extract selected address(es) from a directory for direct insertion into a header, in order to specify the destination(s) for a message.

3.11.3.7 System Distribution Lists.

If required, formal distribution lists that are recognized by the system should be provided so that users can specify multiple addresses with a single distribution list name.

3.11.3.8 Automatic Expansion of Partial Addresses.

Users should be allowed to enter a partial name when specifying addresses, if that will identify a particular destination uniquely.

3.11.3.9 Addressing Replies to Messages Received.

If a user wishes, or is required, to reply to a received message, the appropriate address(es) should be provided automatically, along with a reference to that received message, if required.

3.11.3.10 Editing Address Headers.

Users should be allowed to edit the address fields in the header of a message being prepared for transmission.

3.11.4 Initiating Transmission.

3.11.4.1 User-Initiated Transmission.

Users should initiate data transmission, directly, by entering a explicit SEND command.

3.11.4.2 User Review Before Transmission.

When computer aids are provided for preparing, addressing, and initiating message transmission, users should be allowed to review and change messages prior to transmission.

3.11.4.3 Optional Message Display.

For sending messages, users should be allowed to choose whether to transmit a displayed version, or to transmit directly from computer-stored data files.

3.11.4.4 Computer-Initiated Transmission.

When standard messages must be transmitted, as when a computer is monitoring external events and reporting data change, the computer should initiate transmission automatically.

3.11.4.5 Sender Identification.

When a message is sent, it should contain fields showing the sender's address, and the date and time of message creation and/or transmission. These fields should be appended by the system automation, and should not require the sender to add them.

3.11.4.6 Automatic Queuing for Transmission.

Automatic queuing of outgoing messages should be provided to reduce the need for user involvement in the routine processing of data transmission.

3.11.4.7 Deferring Message Transmission.

Users should be allowed to defer the transmission of prepared messages to be released by later action.

3.11.4.8 Transmission at Specified Date/Time.

Users should be allowed to specify a date, time, or both, for transmitting prepared messages.

3.11.4.9 Return Receipt.

Messages should be transmitted with "return receipt requested" if users will require that capability.

3.11.4.10 Cancel Transmission.

Senders should be allowed to cancel a request for transmission of a message that has not yet been sent.

3.11.4.11 Printing Messages.

Users should be allowed to print copies of transmitted messages in order to make hard-copy records.

3.11.5 Transmission Status Notification.

3.11.5.1 Automatic Protection of Transmitted Data.

Transmitted data should be protected automatically with parity checks to detect and correct any errors that may occur, and buffering until acknowledgement of receipt.

3.11.5.2 Automatic Feedback.

Automatic feedback should be provided to confirm that messages have been sent, or to indicate transmission failures, as necessary, to permit effective user participation in message handling.

3.11.5.3 Send Single Copy.

Only one copy of any message should be transmitted to any individual addressee.

3.11.5.4 Queuing Failed Transmissions.

In the event of transmission failure, automatic queuing should be provided to preserve outgoing messages.

3.11.5.5 Saving Undelivered Messages.

If message transmission is not successful, undelivered messages should be automatically stored.

3.11.5.6 Notification.

If message transmission is not successful, the sender should be notified including an explanation of the problem.

3.11.5.7 Automatic Record Keeping.

When a log of data transmissions is required, a log should be kept automatically, based on user specification of message types and record formats.

3.11.6 Received Message Status Notification.

3.11.6.1 Specifying Sources.

For each type of message received, users should be allowed to choose the method of receipt, i.e., what devices, (files, display, printer) will be the local destination.

3.11.6.2 Queuing Messages.

Provide default logic so that, unless otherwise specified by a user, the computer will route incoming messages automatically to a queue ("in-box"), pending subsequent review and disposition by the user.

3.11.6.3 Nondisruptive Notification of Arriving Messages.

Notification of message arrival should not interfere with the user's other information-handling tasks.

3.11.6.4 Indicating Priority of Received Messages.

In applications where incoming messages will have different degrees of urgency, i.e., different implications for action, recipients should be notified of message priority, and/or other pertinent information.

3.11.6.5 Filters for Message Notification.

Users should be allowed to specify "filters" based on message source, type, or content, that will control what notification is provided for incoming messages.

3.11.6.6 User Review of Messages in Queue.

A convenient means should be provided for users to review received messages in their incoming queue, without necessarily requiring any further disposition action, i.e., without removal from the queue.

3.11.6.7 Filters for Ordering Message Review.

Users should be allowed to specify "filters" based on message source, type, or content, that can control the order in which received messages will be read.

3.11.6.8 Message Review Compatible with Data Display.

Computer aids and procedures for reviewing messages should be consistent with other system capabilities for general data display.

3.11.6.9 Filters for Message Filing.

Users should be allowed to specify "filters" based on message source, type, or content, that will control how messages should be filed, printed and/or discarded.

3.11.6.10 Flexible Design for Data Transmission.

Since data transmission requirements may vary, some means should be provided to make necessary changes to transmission functions.

4. CONTROLS/DISPLAYS AND THEIR ARRANGEMENT.

4.1 CONTROL/DISPLAY INTEGRATION.

4.1.1 General Guidelines.

4.1.1.1 Relationship.

The relationship of a control to its associated display, and the display to the control, should be immediately apparent and unambiguous to the operator. Controls should be located adjacent to (normally under or to the right of) their associated displays, and positioned so that neither the control, nor the hand normally used for setting the control, will obscure the display.

4.1.1.2 Design.

Control-design relationships should be apparent through proximity, similarity of groupings, coding, framing, labeling, and similar techniques.

4.1.1.3 Complexity and Precision.

The complexity and precision required of control manipulation and display monitoring should be consistent with the precision required of the system. Control/display complexity and precision should not exceed the capability of the operator (in terms of discrimination of display detail), or exceed the operator's manipulative capability under the dynamic conditions and environment (in terms of manual dexerity, coordination or reaction time) in which human performance is expected to occur.

4.1.1.4 Feedback.

Feedback on control-response adequacy should be provided as rapidly as possible. Critical control functions, such as those entered by keyboard, should provide adequate feedback to the operator prior to entry, to ensure that the keyed entry is, in fact, errorless and the one that the operator desires to enter.

4.1.1.5 Illumination.

Adjustable illumination should be provided for visual displays, including display, control, and panel labels and critical markings, that must be read at night or under darkened conditions.

4.1.1.6 Simultaneous Access.

If more than one crew member must have simultaneous access to a particular group of controls or displays, the assigned operator should have physical and visual access to all controls, displays, and communication capability necessary to adequately perform assigned tasks.

4.1.2 Position Relationships.

4.1.2.1 Functional Grouping.

Functionally related controls and displays should be located in proximity to one another, and arranged in functional groups, e.g., power, status, test.

4.1.2.1.1 Functional Group Arrangement.

4.1.2.1.1.1 Sequence.

Functional groups of control and displays should be located to provide for left-to-right (preferred) and/or top-to-bottom order of use.

4.1.2.1.1.2 Access.

Providing that the integrity of grouping by function and sequence is not compromised, the more frequently used, and the most important groups should be located in areas of easiest access. Control-display groups required solely for maintenance purposes should be located in positions providing a lesser degree of access relative to operating groups.

4.1.2.1.1.3 Functional Group Marking.

Control display areas in aircraft crew stations should be delineated in accordance with Federal Aviation Administration (FAA) regulations.

4.1.2.2 Location and Arrangement.

Displays and controls should be located and arranged to minimize "head-down" time in aircraft cockpits.

4.1.2.3 Arrangement Within Groups.

Controls and displays within functional groups should be located according to operational sequence and/or function.

4.1.2.3.1 Simultaneous Use.

A visual display, monitored while manipulating a related control, should be located to avoid the possibility of parallax error.

4.1.2.3.2 Emergency Use.

Emergency displays and controls should be located where they can be seen and reached with minimum delay (e.g., warning lights within 30 degrees of the normal line of sight, emergency controls close to their related displays, or the nearest available hand in its nominal position).

4.1.3 Movement Relationships.

4.1.3.1 Lack of Ambiguity.

Display indicators should clearly and unambiguously direct and guide the appropriate control response. The response of a display to control movements should be consistent, predictable, and compatible with the operator's expectations.

4.1.3.2 Time Lag.

The time lag between the response of a system to a control input, and display presentation of the response, should be minimized, consistent with safe and efficient system operation.

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4.1.4 Control/Display Movement Ratio.

4.1.4.1 Minimization of Time.

Control/display ratios for continuous adjustment controls should minimize the total time required to make the desired control movement (i.e., slewing time plus fine adjusting time), consistent with display size, tolerance requirements, viewing distance, and time delays.

4.1.4.2 Range of Display Movement.

When a wide range of display element movement is required, small movement of the control should yield a large movement of the display element. When a small range of display movement is required, a large movement of the control should result in small movement of the display, consistent with final accuracy required.

4.2 VISUAL DISPLAYS.

4.2.1 General.

Visual displays should be utilized to provide the operator with a clear indication of equipment or system conditions for operating under any eventuality, commensurate with the operational and maintenance philosophy of the system.

4.2.1.1 Display Illumination and Light Distribution.

4.2.1.1.1 Display Illumination.

When maximum dark adaptation is not required, low brightness white light (preferably integral and adjustable, as appropriate) should be used. However, when complete dark adaptation is required, low luminance [0.07 - 0.35 candla per square meter (cd/m2)], or 0.02 - 0 .10 foot-Lamberts (fL) red light [greater than 620 nanometers (nm)] should be provided.

4.2.1.1.2 Display Contrast.

Sufficient display contrast should be provided between all information, and its background, to ensure good readability under all expected lighting conditions.

4.2.1.2 Information.

4.2.1.2.1 Content.

The information displayed to an operator should be sufficient to allow the operator to perform the intended mission, and limited to that which is necessary to perform specific actions or to make decisions.

4.2.1.2.2 Precision.

Information should be displayed only within the limits and precision required for specific operator actions or decisions.

4.2.1.2.3 Format.

Information should be presented to the operator in a directly useable form. Requirements for transposing, computing, interpolating, or mentally translating into other units, should be avoided. Additional requirements for computer display formats are contained in section 3.

4.2.1.2.4 Redundancy.

Redundancy in the display of information to a single operator should be avoided, unless it is required to achieve specified reliability.

4.2.1.2.5 Combining Operator/Maintainer Information.

Operator and maintainer information should not be combined in a single display unless the information content and format are well suited to, and time compatible for, both users.

4.2.1.2.6 Display Failure Clarity.

Failure of a display or its circuit should be immediately apparent to the operator.

4.2.1.2.7 Display Circuit Failure.

Failure of the display circuit should not cause a failure in the equipment associated with the display.

4.2.1.2.8 Duration.

Signals and display information should have durations of sufficient length to be reliably detected under expected operator workload and operational environment.

4.2.1.2.9 Timeliness.

Displays that require refreshed information, such as CRT displays, head-up displays, and collimated displays, etc., should be updated in a synchronous manner, where possible. Such displays should also be refreshed to the degree of timeliness required by personnel in the normal operating or servicing mode.

4.2.1.2.10 Advisory and Alerting.

A display presenting simultaneous and integrated information should advise or alert the operator to information that becomes critical within the display.

4.2.1.3 Location and Arrangement.

4.2.1.3.1 Location.

Displays should be located and designed so they can be accurately read without requiring the operator to assume an uncomfortable, awkward, or unsafe position.

4.2.1.3.2 Orientation.

Display faces should be perpendicular to the operator's normal line of sight whenever feasible, and should not be less than $\pi/4$ rad (45 degrees) from the normal line of sight (see figure 4.2.1.3.2-1). Parallax should be minimized.

4.2.1.3.3 Reflection.

Displays should be constructed, arranged, and mounted to prevent reduction of information transfer due to the reflection of the ambient illumination from the display screen. Reflection of instruments and consoles, in windshields and other enclosures, should be avoided. If necessary, techniques (such as shields and filters) should be employed to ensure that system performance will not be degraded.

4.2.1.3.4 Vibration.

Vibration of visual displays should not degrade user performance below the level required for mission accomplishment.

4.2.1.3.5 Grouping.

All displays necessary to support an operator, or sequence of activities, should be grouped together.

4.2.1.3.6 Function and Sequence.

Displays should be arranged in relation to one another according to their sequence of use, or the functional relations of the components they represent. They should be arranged in sequence within functional groups, whenever possible, to provide a viewing flow from left to right or top to bottom.
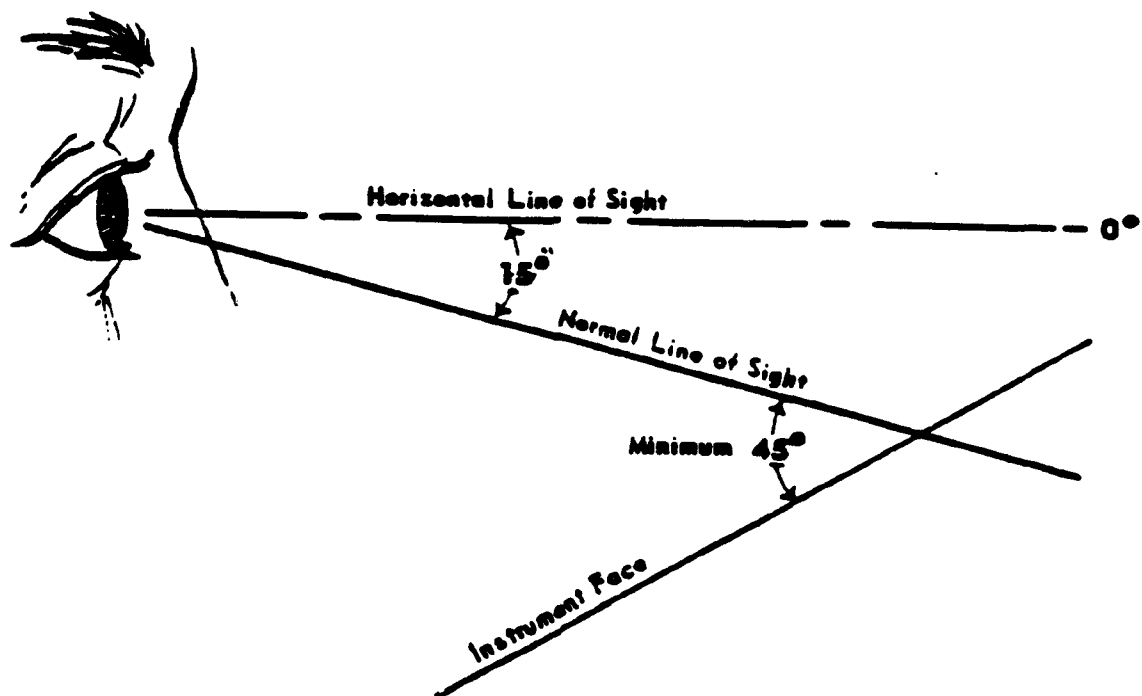
Horizontal Line of Sight

0°

15°

Normal Line of Sight

Minimum 45°

Instrument Face

FIGURE 4.2.1.3.2-1.   LINES OF SIGHT

4.2.1.3.7 Frequency of Use.

Displays used most frequently should be grouped together and placed in the optimum visual zone (see figure 4.2.1.3.7-1).

4.2.1.3.8 Importance.

Important or critical displays should be located in a privileged position, in the optimum projected visual zone, or otherwise highlighted.

4.2.1.3.9 Maximum Viewing Distance.

The viewing distance, from the eye reference point of the seated operator to displays located close to their associated controls, should not exceed 635 millimeters (mm) (25 inches (in)). Otherwise, there is no maximum limit other than that imposed by legibility limitations, which should be compensated for by proper design.

4.2.1.3.10 Minimum Viewing Distance.

The viewing distance to displays should never be less than 330 mm (13 in), and preferably not less than 510 mm (20 in).

4.2.1.3.11 Aircrew Station Signals.

Signals for aircrew stations should be in accordance with FAA regulations. Human engineering design for crew members who occupy positions other than on the flight deck (such as in multi-engined specialized aircraft) should conform with the guidelines in those regulations.

4.2.1.4 Coding.

4.2.1.4.1 Objectives.

Coding techniques should be used to facilitate identification of critical information within a display.

4.2.1.4.2 Techniques.

Displays should be coded by color, size, location, shape, or flash coding, as applicable.

4.2.1.4.3 Standardization.

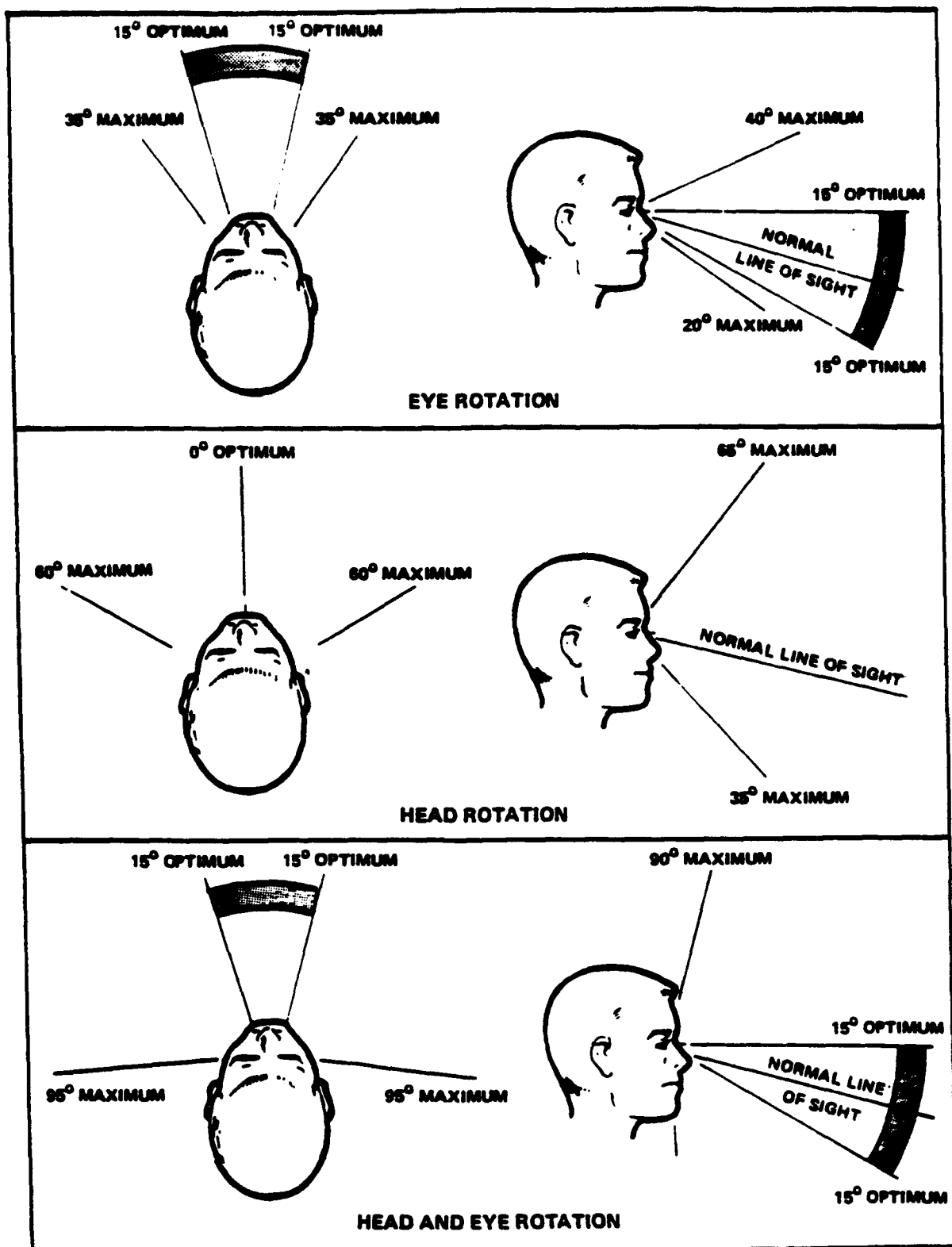All coding within the system should be uniform.

FIGURE 4.2.1.3.7-1. VERTICAL AND HORIZONTAL VISUAL FIELD

4.2.1.4.4 Symbology.

Symbology for aircrew displays should be in accordance with FAA regulations.

4.2.2 CRT Displays.

4.2.2.1 Viewing Distance.

A 400 mm (16 in) viewing distance should be provided whenever practicable. Displays placed at viewing distances greater than 400 mm (16 in) should be appropriately modified in aspects such as display size, symbol size, brightness ranges, line-pair spacing, and resolution.

4.2.2.2 Screen Luminance.

The ambient illuminance should not contribute more than 25 percent of screen brightness through diffuse reflection and phosphor excitation. A control should be provided to vary the CRT luminance from 10 percent of minimum ambient luminance to full CRT luminance.

4.2.2.3 Luminance Range of Adjacent Surfaces.

The luminance range of surfaces, immediately adjacent to CRT screens, should be between 10 percent and 100 percent of screen background luminance. With the exception of emergency indicators, no light source in the immediate surrounding area should be of a greater luminance than the CRT signal.

4.2.2.4 Ambient Illuminance.

The ambient illuminance should be appropriate for other visual functions (e.g., setting controls, reading instruments, maintenance), but should not degrade the visibility of data on the CRT display. When the CRT display is in variable ambient illuminance, controls should be provided to dim all light sources, including illuminated panels, indicators and switches in the immediate surround. Automatic adjustment of CRT brightness may be used if the CRT brightness is automatically adjusted as a function of ambient illuminance, and the range of automatic adjustment is adequate for the full range of ambient illuminance.

4.2.2.5 Reflected Glare.

Reflected glare should be minimized by proper placement of the screen relative to the light source, use of a hood or shield, or optical coatings on the CRT or filter control over the light source.

4 2.2.6 Adjacent Surfaces.

Surfaces adjacent to the display screen should have a dull matte finish.

4.2.3 Printers.

4.2.3.1 Use.

Printers should be used when a visual record of data is necessary or desirable.

4.2.3.2 Visibility.

The printed matter should not be hidden, masked or obscured in a manner that impairs direct reading.

4.2.3.3 Contrast.

A minimum of 3.0 luminance contrast should be provided between the printed material and the background on which it is printed.

4.2.3.4 Illumination.

The printer should be provided with internal illumination, if the printed matter is not legible in the planned operational ambient illumination.

4.2.3.5 Annotation.

Where applicable, printers should be mounted so that the printed matter (e.g., paper, metalized paper) may be easily annotated while still in the printer.

4.2.3.6 Legibility.

The printer output should be free from character line misregistration, tilt, or smear.

4.2.3.7 Control, Replenishment and Service.

Printers should conform to these guidelines with regard to:

    a. Controls and displays used to start, stop, or adjust the machine, and critical operating elements.

    b. Positive indication of the remaining supply of materials (e.g., paper).

    c. Insertion, adjustment for operation or removal of paper, or replacement of other items determined to be operator tasks, without requiring disassembly, special equipment or tools.

d.   Minor on site servicing by a technician, e.g., adjustment of drive system, cleaning, or replacement of operating items that ordinarily would not be available.

4.2.4 Light Emitting Diode (LED).

4.2.4.1 Use.

LEDs may be used for transilluminated displays, including legend and simple indicator lights, and for matrix (alphanumeric) displays, only if the display is bright enough to be readable in the environment of intended use (enclosure, bright sunlight, low temperature).

4.2.4.2 Intensity Control.

The dimming of LEDs should be compatible with the dimming of incandescent lamps.

4.2.4.3 Color.

Red LEDs should not be located in the proximity of red warning lights.

4.2.4.4 Lamp Testing.

LED indicator lights, with 100,000 hours or longer mean time between failure (MTBF), should not require a lamp test capability.

4.2.5 Dot Matrix/Segmented Displays.

4.2.5.1 General.

The following design criteria should be applied to those displays (LED, CRT, gas discharge, liquid crystal and incandescent) used for the presentation of alphanumeric and symbolic information.

4.2.5.2 Use.

Dot matrix 14-segment and 16-segment displays may be used when the presentation of alphanumeric, vector-graphic, symbolic or real-time information is required. Seven-segment displays should only be used for applications requiring numeric information.

4.2.5.3 Symbol Definition.

The smallest definition for a dot matrix should be five by seven dots, with seven by nine preferred. If system requirements call for symbol rotation, a minimum of 8 by 11 is acceptable, with 15 by 21 preferred.

4.2.5.4 Alphanumeric Character and Symbol Sizes.

Alphanumeric and symbolic characters should not subtend less than 4.7 miliradians (mrad) (16 minutes (min)) of visual angle. Flight display characters should subtend not less the 7 mrad (24 min) of visual angle.

4.2.5.5 Use of Upper Case.

Alphanumeric characters should be upper case on dot matrix displays.

4.2.5.6 Viewing Angle.

The optimum viewing angle is perpendicular to the display. Dot matrix, or segmented displays, should not be presented for viewing at an angle larger than 610 mrad (35 degrees) off axis.

4.2.5.7 Emitter Color.

Monochromatic displays should use, in order of preference, green (555nm), Yellow (575nm), orange (585nm), and red (660nm). Blue emitters should be avoided.

4.2.5.8 Intensity Control.

Dimming controls should be provided, where applicable, to maintain appropriate legibility and operator dark adaptation level.

4.2.5.9 Display Testing.

See section 4.2.4.4.

4.2.5.10 Location of Red Alphanumeric LEDs/Segmented Displays.

See section 4.2.4.3.

4.2.6 Electroluminescent Displays.

4.2.6.1 Use.

Electroluminescent displays may be used wherever system requirements dictate the use of transilluminated displays. In addition, they may replace existing mechanical instrumentation since they offer advantages of lighter weight, conservation of panel space, lower power requirements, lack of heat production, uniform distribution of illumination, longer life, elimination of parallax, and flexibility of display. Electroluminescent displays may also be used where sudden lamp failure could result in catastrophic consequences.

4.2.6.2 Alphanumeric Character and Symbol Sizes.

The height of alphanumeric characters and geometric and pictorial symbols should not subtend less than 4.5 mrad (15 min) of visual angle. Alphanumerical characters should be composed of upper case letters. Flight display alphanumerics should not subtend less than 7 mrad (24 min) of visual angle to ensure adequate legibility under aircraft environmental conditions.

4.3 AUDIO DISPLAYS.

4.3.1 General.

4.3.1.1 Use.

Audio displays should be provided when:

a. The information to be processed is short, simple, and transitory, requiring immediate or time-based response.

b. The common mode of visual display is restricted by over-burdening, ambient light variability or limitation, operator mobility, degradation of vision by vibration, high-g-forces, hypoxia, or other environmental considerations, or anticipated operator inattention.

c. The criticality of transmission response makes supplementary or redundant transmission desirable.

d. It is desirable to warn, alert, or cue the operator to subsequent additional response.

e. Custom or usage has created anticipation of an audio display.

f. Voice communication is necessary or desirable.

4.3.1.2 Signal Type.

When an audio presentation is required, the optimum type of signal should be presented in accordance with table 4.3.1.2-1.

4.3.1.3 False Alarms.

The design of audio display devices and circuits should preclude false alarms.

4.3.1.4 Failure.

The audio display device and circuit should be designed to preclude warning signal failure in the event of system or equipment failure and vice versa.

TABLE 4.3.1.2-1 FUNCTIONAL EVALUATION OF AUDIO SIGNALS

FUNCTION	TYPE OF SIGNAL		
	TONES (Periodic)	COMPLEX SOUNDS (Non-Periodic)	SPEECH
QUANTITATIVE INDICATION	**POOR** Maximum of 5 to 6 tones absolutely recognizable.	**POOR** Interpolation between signals inaccurate.	**GOOD** Minimum time and error in obtaining exact value in terms compatible with response.
QUALITATIVE INDICATION	**POOR-TO-FAIR** Difficult to judge approximate value and direction of deviation from null setting unless presented in close temporal sequence.	**POOR** Difficult to judge approximate deviation from desired value.	**GOOD** Information concerning displacement, direction, and rate presented in form compatible with required response.
STATUS INDICATION	**GOOD** Start and stop timing. Continuous information where rate of change of input is low.	**GOOD** Especially suitable for irregularly occurring signals (e.g., alarm signals).	**POOR** Inefficient; more easily masked; problem of repeatability.
TRACKING	**FAIR** Null position easily monitored; problem of signal-response compatibility.	**POOR** Required qualitative indications difficult to provide.	**GOOD** Meaning intrinsic in signal.
GENERAL	Good for automatic communication of limited information. Meaning must be learned. Easily generated.	Some sounds available with common meaning (e.g., fire bell). Easily generated.	Most effective for rapid (but not automatic) communication of complex, multidimensional information. Meaning intrinsic in signal and context when standardized. Minimum of new learning required.

4.3.1.5 Circuit Test.

All audio displays should be equipped with circuit test devices, or other means of operability test.

4.3.1.6 Aircrew Stations.

Audio signals for air crew stations should conform to FAA regulations, where applicable.

4.3.1.7 Use with Several Visual Displays.

One audio signal may be used in conjunction with several visual displays, provided that immediate discrimination is not critical to personnel safety, or system performance.

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4.3.2 Audio Warnings.

4.3.2.1 Warning Signals.

Audio signals should be provided, as necessary, to warn personnel of impending danger, to alert an operator to a critical change in system or equipment status, and to remind the operator of a critical action or actions that must be taken. An alerting/warning system or signal should provide the operator with a greater probability of detecting the triggering condition than his normal observation would provide, in the absence of the alerting/warning system or signal. NOTE: Certain audio signals have been standardized for aircraft use by joint service and international agreement. Stipulation of audio signals for future aircraft design should be in consonance with these agreements.

4.3.2.2 Nature of Signals.

Audio warning signals should normally consist of two elements: an alerting signal, and an identifying or action signal.

4.3.2.2.1 Two Element Signals.

When reaction time is critical and a two-element signal is necessary, an alerting signal of 0.5 s duration should be provided. All essential information should be transmitted in the first 2.0 s of the identifying of action signals.

4.3.2.2.2 Single Element Signal.

When reaction time is critical, signals should be of short duration. If a single element signal is permissable, all essential information should be transmitted in the first 0.5 s.

4.3.2.3 Caution Signals.

Caution signals should be readily distinguishable from warning signals, and should be used to indicate conditions requiring awareness, but not necessarily immediate action.

4.3.2.4 Relation to Visual Displays.

When used in conjunction with visual displays, audio warning devices should be supplementary or supportive. The audio signal should be used to alert and direct operator attention to the appropriate visual display.

4.4 CONTROLS.

4.4.1 General Guidelines.

4.4.1.1 Arrangement and Grouping.

4.4.1.1.1 Grouping.

All controls which function in sequential operation necessary to a particular task, or which operate together, should be grouped with their associated displays. When several steps of a sequence are selected by one control, the steps should be arranged by order of occurrence, to minimize control movements and prevent cycling through unnecessary steps. Cycling through the control's ON/OFF position should be avoided.

4.4.1.1.2 Sequential Operation.

Where sequential operations follow a fixed pattern, controls should be arranged to facilitate operation (e.g., in a pattern left-to-right and top-to-bottom, as a printed page).

4.4.1.1.3 Location of Primary Controls.

The most important and frequently used controls should have the most favorable position, with respect to ease of reaching and grasping (particularly rotary controls and those requiring fine settings).

4.4.1.1.4 Consistency.

The arrangement of functionally similar, or identical, primary controls should be consistent from panel to panel throughout the system or equipment. A movement of a control to the right or left should result in a corresponding movement of a displayed element to the right or left.

4.4.1.1.5 Remote Controls.

Where controls are operated at a position remote from the display, they should be arranged to facilitate direction-of-movement consistency.

4.4.1.1.6 Maintenance and Adjustment.

In general, controls used solely for maintenance and adjustment should be covered during normal equipment operation, but readily accessible and visible to the maintenance technician, when required.

4.4.1.1.7 Spacing.

Minimum spacing between controls should comply with table
4.4.1.1.7-1.

TABLE 4.4.1.1.7-1 MINIMUM SEPARATION DISTANCES FOR CONTROLS

	TOGGLE SWITCHES	*PUSH-BUTTONS	CONTINUOUS ROTARY CONTROLS	ROTARY SELECTOR SWITCHES	DISCRETE THUMBWHEEL CONTROLS
TOGGLE SWITCHES	SEE FIG 13	13 mm (0.5 in.)	19 mm (0.75 in.)	19 mm (0.75 in.)	13 mm (0.5 in.)
*PUSHBUTTONS	13 mm (0.5 in.)	*	13 mm (0.5 in.)	13 mm (0.5 in.)	13 mm (0.5 in.)
CONTINUOUS ROTARY CONTROLS	19 mm (0.75 in.)	13 mm (0.5 in.)	See Figure 4.4.4.2-1	25 mm (1.0 in.)	19 mm (0.75 in.)
ROTARY SELECTOR SWITCHES	19 mm (0.75 in.)	13 mm (0.5 in.)	25 mm (1.0 in.)	See Figure 4.4.2.1.7-1	19 mm (0.75 in.)
DISCRETE THUMBWHEEL CONTROLS	13 mm (0.5 in.)	13 mm (0.5 in.)	19 mm (0.75 in.)	19 mm (0.75 in.)	See Figure 4.4.3.7-1

* See Figure 4.4.7.5-1

*For pushbuttons not separated by barriers

All values are for one hand operation. Distances are measured
from edge to edge of each control.

4.4.1.2 Coding.

4.4.1.2.1 Methods and Requirements.

Where coding is used to differentiate among controls, application
of the code should be uniform throughout the system.

4.4.1.2.2 Size-Coding.

No more than three different sizes of controls should be used in
coding controls for discrimination by absolute size. When knob
diameter is used as the coding parameter, differences between
diameters should not be less than 13 mm (0.5 in). When knob
thickness is the coding parameter, differences between
thicknesses should not be less than 10mm (0.4 in).

4.4.1.2.3 Color-Coding.

4.4.1.2.3.1 Immediate Action Controls.

Color coding of immediate action controls for aircraft should conform to FAA regulations.

4.4.1.2.3.2 Relation to Display.

When color-coding must be used to relate a control to its corresponding display, the same color should be used for both the control and the display.

4.4.1.2.3.3 Control Panel Contrast.

The color of the control should provide contrast between the panel background and the control.

4.4.1.2.3.4 Ambient Lighting and Color-Coding Exclusion.

Color coding should be compatible with anticipated ambient lighting throughout the mission. Color-coding should not be used as the primary code if the spectral characteristics of ambient light, or the operator's adaptation to it varies due to such factors as solar glare, filtration, or variation from natural to artificial light.

4.4.1.3 Labeling of Controls.

Control labeling should conform to the criteria in section 4.5.

4.4.1.4 Blind Operation.

Where "blind" operation is necessary, hand controls should be shape-coded, or separated from adjacent controls by at least 125 mm (5 in).

4.4.1.5 Prevention of Accidental Actuation.

4.4.1.5.1 Location and Design.

Controls should be designed and located so that they are not susceptible to being moved accidently, particularly critical controls whose inadvertent operation might cause damage to equipment, injury to personnel, or degradation of system functions.

4.4.1.5.2 Internal Controls.

Internal or hidden controls should be protected, because it is usually not obvious that such controls have been disturbed, and it may be difficult and time consuming to locate and readjust them.

4.4.1.5.3 Rapid Operation.

Any method of protecting a control from inadvertent operation should not preclude operation within the time required.

4.4.1.5.4 Methods.

For situations in which controls must be protected from accidental actuation, one or more of the following methods, as applicable, should be used:

    a. Locate and orient the controls so that the operator is not likely to strike or move them accidently in the normal sequence of control movements.

    b. Recess, shield, or otherwise surround the controls by physical barriers. The control should be entirely contained within the envelope described by the recess or barrier.

    c. Cover or guard the controls. Safety or lock wire should not be used.

    d. Provide the controls with interlocks so that extra movement, (e.g., a side movement out of a detent position or a pull-to-engage clutch) or the prior operation of a related or locking control, is required.

    e. Provide the controls with resistance (i.e., viscous or coulomb friction, spring-loading, or inertia) so that definite or sustained effort is required for actuation.

    f. Provide the controls with a lock to prevent the control from passing through a position without delay when strict sequential activation is necessary (i.e., the control moved only to the next position, then delayed).

    g. Design the controls for operation by rotary action.

4.4.2 Rotary Selector Switches.

4.4.2.1 Use.

Rotary selector switches should be used for discrete functions when three or more detented positions are required. Rotary selector switches should not be used for a two-position function unless prompt visual identification of control position is of primary importance, and speed of control operation is not critical.

4.4.2.2 Moving Pointer.

Rotary selector switches should be designed with a moving pointer and a fixed scale.

4.4.2.3 Shape.

Moving pointer knobs should be shaped with parallel sides, and the index end tapered to a point. Exceptions may be justified when pointer knobs are shape-coded, or when space is restricted and torque is light. Shape-coding should be used when a group of rotary controls used for different functions is placed on the same panel, and control confusion might otherwise result.

4.4.2.4 Positions.

A rotary selector switch which is not visible to the operator during normal system operation should have no more that 12 positions. A rotary switch which is constantly visible to the operator should have not more than 24 positions. In addition, the following guidelines apply:

a. Rotary switch positions should not be placed opposite each other unless knob shape precludes confusion as to which end of the knob is the pointer.

b. The switch resistance should be elastic, building up, then decreasing as each position is approached. The control should snap into position without stopping between adjacent positions.

4.4.2.5 Contrast.

A reference line should be provided on rotary switch controls. This line should have at least 3.0 luminance contrast with the control color under all lighting conditions.

4.4.2.6 Parallax.

The knob pointer should be mounted sufficiently close to its scale to minimize parallax between the pointer and the scale markings. When viewed from the normal operator's position, the parallax errors should not exceed 25 percent of the distance between scale markings.

4.4.2.7 Dimensions, Resistance, Displacement, and Separation.

Control dimensions, resistance, displacement, and separation between adjacent edges of areas swept by rotary selector switches, should conform to the criteria in figure 4.4.2.7-1.
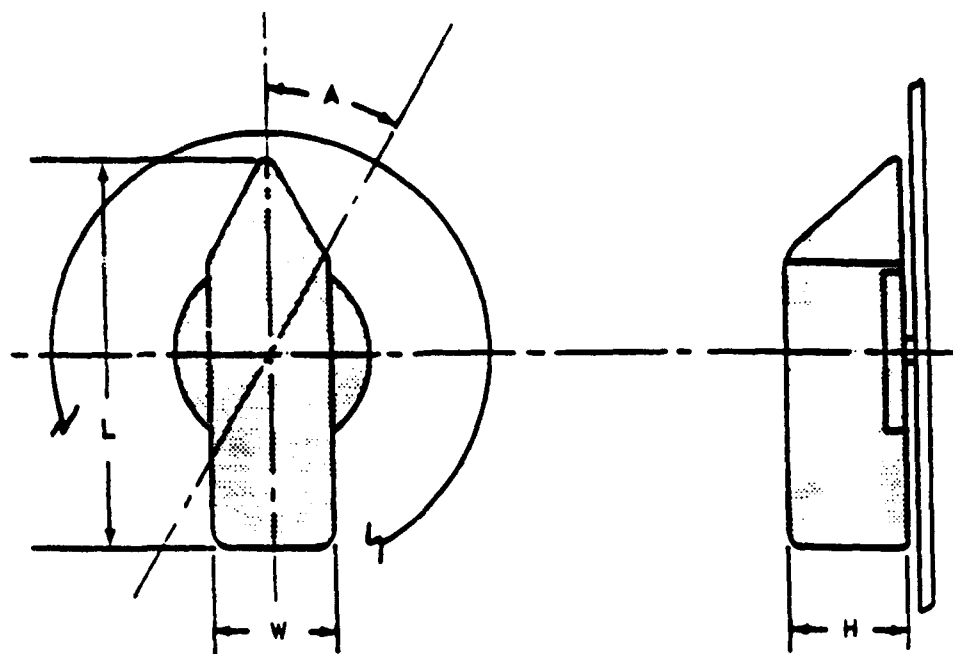
	DIMENSIONS			RESISTANCE
	L Length	**W** Width	**H** Depth	
Minimum	25 mm (1 in.)		16 mm (5/8 in.)	115 mN · m (1 in.–lb)
Maximum	100 mm (4 in.)	25 mm (1 in.)	75 mm (3 in.)	680 mN · m (6 in.–lb)

	DISPLACEMENT		SEPARATION	
	A		One-Hand Random	Two-Hand Operation
	*	* *		
Minimum	262 mrad (15°)	525 mrad (30°)	25 mm (1 in.)	75 mm (3 in.)
Maximum	700 mrad (40°)	1570 mrad (90°)	-	-
Preferred	-	-	50 mm (2 in.)	125 mm (5 in.)

*For facilitating performance.

**When special engineering requirements demand large separation or when tactually
("blind") positioned controls are required.

FIGURE 4.4.2.7-1.   ROTARY SELECTOR SWITCH

4.4.3 Discrete Thumbwheel Controls.

4.4.3.1 Application.

Thumbwheel controls may be used if the function requires a compact digital control-input device (for a series of numbers), and a readout of these manual inputs for verification. The use of thumbwheels for any other purposes is discouraged. Detent indexing units should provide 10 positions (0-9) in digital or binary (3 or 4 bits and complement) outputs.

4.4.3.2 Shape.

Each position around the circumference of a discrete thumbwheel should have a concave surface, or should be separated by a high-friction area which is raised from the periphery of the thumbwheel. The thumbwheels should not preclude viewing the digits within $\pi/6$ rad (30 degrees) viewing angle to the left and right of a perpendicular to the thumbwheel digits.

4.4.3.3 Coding.

Thumbwheel controls may be coded by location, labeling, and color (e.g., reversing the colors of the least significant digit wheel as on typical odometers). Where used as input devices, thumbwheel switch OFF or NORMAL positions should be color coded to permit a visual check that the digits have been reset to their normal position.

4.4.3.4 Direction of Movement.

Moving the thumbwheel edge forward, upward, or to the right, should increase the setting.

4.4.3.5 Numerals.

4.4.3.5.1 Internal Illuminance.

For areas in which ambient illumination will provide display brightness below 3.5 cd/m2 (1 foot (ft) -L), the thumbwheel should be internally illuminated. Digits should appear as illuminated characters on a black background, and their dimensions should approximate the following:

    a. Height: 4.8 mm (3/16 in)
    b. Height-to-Width Ratio: 3:2
    c. Height-to-Stroke Width Ratio: 10:1

4.4.3.5.2 External Illuminance.

In areas where ambient illumination will provide a display luminance above 3.5 cd/m2 (1 ft-L), internal illumination is not

required. Digits should be bold, black numerals engraved on a light (or white) thumbwheel background. The dimensions should approximate those specified in section 4.4.3.5.1, except that the height-to-stroke width ratio should be approximately 5:1.

4.4.3.6 Visibility.

Thumbwheel design should permit viewing of inline digital read-out from all operator positions.

4.4.3.7 Dimensions.

Control dimensions should conform to the criteria in figure 4.4.3.7-1.

4.4.3.8 Resistance.

Detents should be provided for discrete position thumbwheels. Resistance should be elastic, building up and then decreasing as each detent is approached, so that the control snaps into position without stopping between adjacent detents. The resistance should be within the limits indicated in figure 4.4.3.7-1.

4.4.3.9 Separation.

The separation between adjacent edges of thumbwheel controls should conform to the criteria in figure 4.4.3.7-1, and should be sufficient to preclude accidental activation of adjacent controls during activation of desired controls.

4.4.4 Knobs.

4.4.4.1 Use.

Knobs should be used when low forces or precise adjustments of a continuous variable are required. A moving knob with fixed scale is preferred over a moving scale with fixed index, for most tasks. If positions of single revolution controls must be distinguished, a pointer or marker should be available on the knob.

4.4.4.2 Dimensions, Torque and Separation.

The dimensions of knobs should be within the limits specified in figure 4.4.4.2-1. Within these ranges, knob size is relatively unimportant, provided the resistance is low and the knob can be easily grasped and manipulated. When panel space is extremely limited, knobs should approximate the minimum values, and should have resistance as low as possible without permitting the setting to be changed by vibration or merely touching the control.
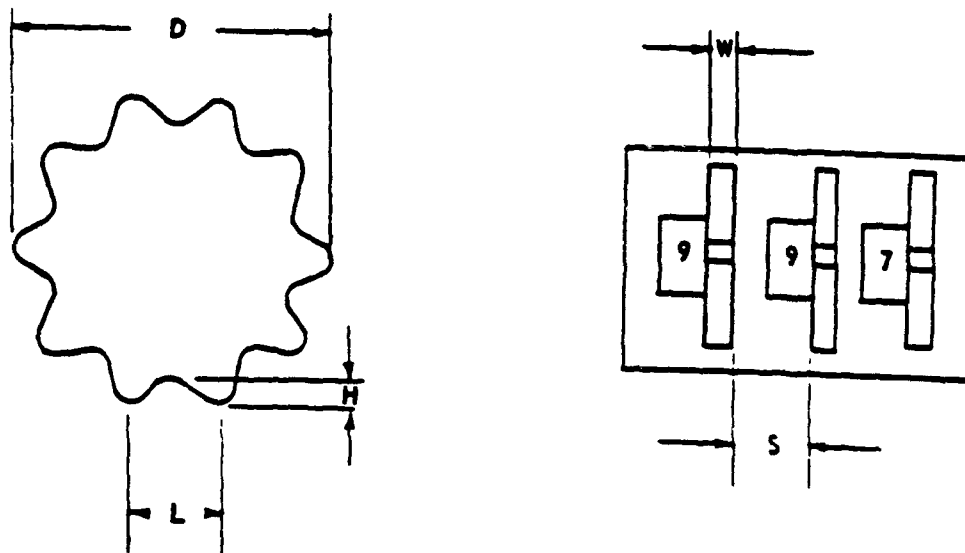
	D	L TROUGH	W	H	S	
	DIAMETER	DISTANCE	WIDTH	DEPTH	SEPARATION	RESISTANCE
MINIMUM	30 mm (1-1/8 in.)	11 mm (7/16 in.)	3 mm (1/8 in.)	3 mm (1/8 in.)	10 mm (13/32 in.)	1.7 N (6 oz)
MAXIMUM	75 mm (3 in.)	19 mm (3/4 in.)		13 mm (1/2 in.)		5.6 N (20 oz)

FIGURE 4.4.3.7-1.   DISCRETE THUMBWHEEL CONTROL

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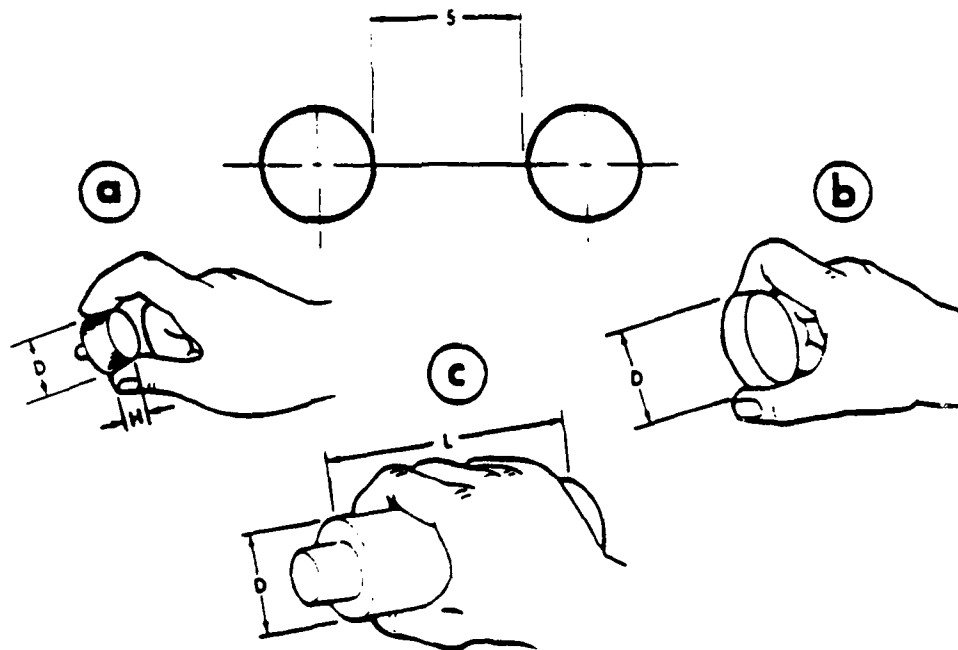
DIMENSIONS					
(a) Fingertip Grasp		**(b) Thumb and Finger Encircled**		**(c) Palm Grasp**	
H Height	**D** Diameter	**D** Diameter		**D** Diameter	**L** Length
Minimum	13 mm (1/2 in.)	10 mm (3/8 in.)	25 mm (1 in.)		38 mm (1-1/2 in.)	75 mm (3 in.)
Maximum	25 mm (1 in.)	100 mm (4 in.)	75 mm (3 in.)		75 mm (3 in.)	

TORQUE		SEPARATION	
		S One Hand Individually	**S** Two Hands Simultaneously
	*	**		
Minimum			25 mm (1 in.)	50 mm (2 in.)
Optimum			50 mm (2 in.)	125 mm (5 in.)
Maximum	32 mN-m (4-1/2 in.-oz.)	42 mN-m (6 in.-oz.)		

*To and including 25 mm (1.0 in.) diameter knobs
**Greater than 25 mm (1.0 in.) diameter knobs

FIGURE 4.4.4.2-1.   KNOBS

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Resistance and separation between adjacent edges of knobs should conform to figure 4.4.4.2-1.

4.4.4.3 Knob Style.

Unless otherwise specified by the procuring activity, control knob style should conform to MIL-STD-1348.

4.4.5 Ganged Control Knobs.

4.4.5.1 Application.

Ganged knob assemblies may be used in limited applications when panel space is at a premium. Two-knob assemblies are preferred. Three-knob configurations should be avoided. Ganged knob configurations should not be used when extremely accurate or rapid operations are required, or when frequent changes are necessary.

4.4.5.2 Dimensions and Separation.

See figure 4.4.5.2-1.

4.4.5.3 Resistance.

Resistance should conform to requirements in figure 4.4.5.2-1. Knobs should be serrated. Fine serration should be used on precise adjustment knobs; coarse serration should be used on gross adjustment knobs.

4.4.5.4 Marking.

An indexing mark or pointer should be provided on each knob. Marks or pointers should differ sufficiently to make it apparent which knob indexing mark is being observed.

4.4.5.5 Knob/Display Relationship.

When each knob of a ganged assembly must be related to an array of visual displays, the knob closest to the panel should relate to the left-most display in a horizontal array, or the uppermost display in a vertical array (see figure 4.4.5.2-1).

4.4.5.6 Inadvertent Operation.

When it is critical to prevent inadvertent activation of one ganged knob as the other is being adjusted, a secondary knob control movement should be provided (e.g., pressing the top knob before it can be engaged with its control shaft). Where inadvertent movement is undesirable but not necessarily critical,
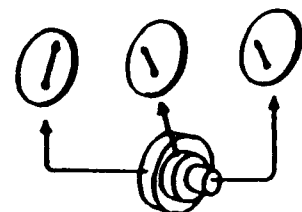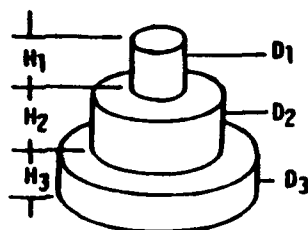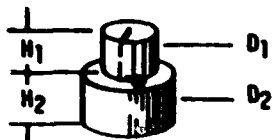
GANGED KNOB/DISPLAY ASSOCIATION

DIMENSIONS									
TWO KNOB ASSEMBLY				THREE KNOB ASSEMBLY					
H_1	H_2	D_1	D_2	H_1	H_2	H_3	D_1	D_2	D_3
MINIMUM 16 mm (5/8")	13 mm (1/2")	13 mm (1/2")	22 mm (7/8")	19 mm (3/4")	19 mm (3/4")	6 mm (1/4")	13 mm (1/2")	44 mm (1-3/4")	75 mm (3")
MAXIMUM			100 mm (4")						100 mm (4")

TORQUE		SEPARATION			
		ONE HAND INDIVIDUALLY		TWO HANDS SIMULTANEOUSLY	
*	**	BARE	GLOVED	BARE	GLOVED
MINIMUM		25 mm (1")	63 mm (2-1/2")	50 mm (2")	90 mm (3-1/2")
OPTIMUM		50 mm (2")	90 mm (3-1/2")	75 mm (3")	100 mm (4")
MAXIMUM 32 mN·m (4-1/2 in.-oz.)	42 mN·m (6 in.-oz.)				

*To and including 25 mm (1") diameter knobs.
**Greater than 25 cm (1") diameter knobs.

FIGURE 4.4.5.2-1.   GANGED KNOBS

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knob diameter/depth relationships should be optimized as shown in figure 4.4.5.2-1. Contrasting colors between knobs may also be used to improve individual knob identification.

4.4.6 Continuous Adjustment Thumbwheel Controls.

4.4.6.1 Use.

Continuously adjustable thumbwheel controls may be used as an alternative to rotary knobs when the application will benefit from the compactness of the thumbwheel device.

4.4.6.2 Orientation and Movement.

Thumbwheels should be oriented and move in the directions specified in figure 4.4.6.2-1.

4.4.6.3 Turning Aids.

The rim of the thumbwheel should be serrated, or provided with a high friction surface, to aid the operator in manipulating the control.

4.4.6.4 Dimensions, Separation and Resistance.

Dimensions, separation and resistance should conform to criteria shown in figure 4.4.6.2-1.

4.4.6.5 Labeling and Visibility.

Marking and labeling should conform to the guidelines, with respect to visibility of markings and legibility of label alphanumerics.

4.4.6.6 OFF Position.

A detent should be provided for continuous thumbwheels having an OFF position.
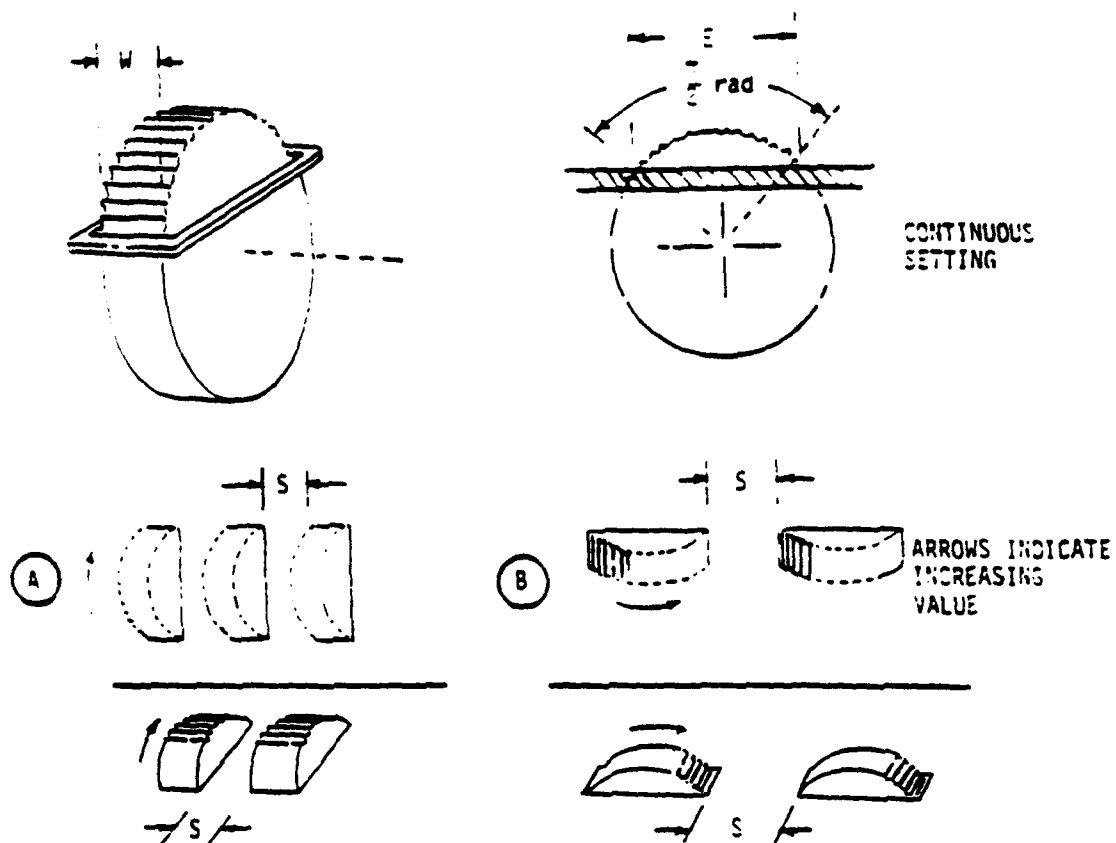
4.4.7 Push Buttons.

4.4.7.1 Use.

Push buttons should be used when a control, or an array of controls, is needed for momentary contact, or for activating a locking circuit, particularly in high frequency-of-use situations.

4.4.7.2 Shape.

The push button surface should normally be concave (indented) to fit the finger. When this is impractical, the surface should

CONTINUOUS
SETTING

A

B ARROWS INDICATE
INCREASING
VALUE

| | E RIM EXPOSURE | W WIDTH | S | | RESISTANCE |
			A	B	
MINIMUM	25 mm * (1")	3 mm * (1/8")	25 mm (1") Add 13 mm (1/2") for gloves	50 mm (2") Add 25 mm (1") for gloves	TO MINIMIZE EFFECTS OF INADVERTENT INPUT IF OPERATOR SUBJECT TO MOTION
MAXIMUM	100 mm (4")	23 mm (7/8")	N/A	N/A	3.3 N (12 oz.)

*Preferred. Some miniature applications may require less.

FIGURE 4.4.6.2-1.   THUMBWHEEL ADJUSTMENT CONTROLS

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provide a high degree of frictional resistance to prevent
slipping.

4.4.7.3 Positive Indication.

A positive indication of control activation should be provided
(e.g., snap feel, audible click, or integral light).

4.4.7.4 Channel or Cover Guard.

A channel or cover guard should be provided when it is imperative
to prevent accidental activation of the controls. When a cover
guard is in the open position, it should not interfere with
operation of the protected device or adjacent controls.

4.4.7.5 Dimensions, Resistance, Displacement, and Separation.

Except for use of push buttons in keyboards, control dimensions,
resistance, displacement, and separation between adjacent edges
of finger or hand-operated pushbuttons should conform to the
criteria in figure 4.4.7.5-1.

4.4.7.6 Interlocks or Barriers.

Mechanical interlocks or barriers may be used instead of spacing
as shown in figure 4.4.7.5-1.

4.4.8 Keyboards.

4.4.8.1 Use.

Arrangements of push buttons in the form of keyboards should be
used when alphabetic, numeric, or special function information is
to be entered into a system.

4.4.8.2 Layout and Configuration.

The key configuration and the number of keys are dependent upon
the predominant type of information to be entered into the
system. The major forms that keyboards can take, which aid in
the entry of such information, are given below:

    a. Numeric keyboard. Keyboard configurations used to enter
solely numeric information should be a 3 x 3 + 1 matrix, with the
zero digit centered on the bottom row.

    b. Alpha-numeric keyboard. Keyboard configurations for
entry of text and some numeric information should conform to MIL-
STD-1280 (see figure 3.2.2.2-1). For some applications, the
entry of data varies from primarily text to primarily numeric.
For these applications two alternatives are preferred: provide a
keyboard of the type shown in figure 2 of MIL-STD-1280 (where
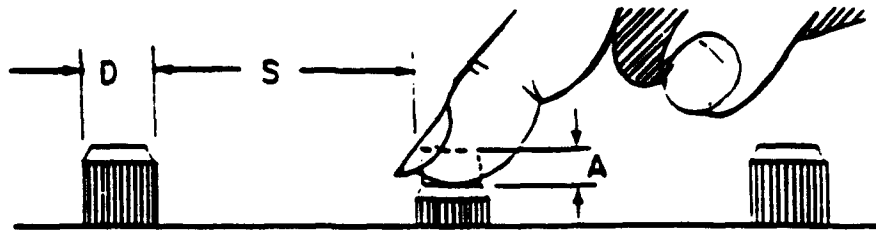
DIMENSIONS			RESISTANCE		
DIAMETER D				**Different**	
	Fingertip	Thumb or Palm	Single Finger	Fingers	Thumb or Palm
Minimum	9.5 mm (3/8 in.)	19 mm (3/4 in.)	2.8 N (10 oz.)	1.4 N (5 oz.)	2.8 N (10 oz.)
Maximum	25 mm (1 in.)		11 N (40 oz.)	5.6 N (20 oz.)	23 N (80 oz.)

DISPLACEMENT		
A		
	Fingertip	Thumb or Palm
Minimum	2 mm (5/64 in.)	3 mm (1/8 in.)
Maximum	6 mm (1/4 in.)	38 mm (1-1/2 in.)

SEPARATION				
S				
	Single Finger	Single Finger Sequential	Different Fingers	Thumb or Palm
Minimum	13 mm (1/2 in.)	6 mm (1/4 in.)	mm (1/4 in.)	25 mm (1 in.)
Preferred	50 mm (2 in.)	13 mm (1/2 in.)	mm (1/2 in.)	150 mm (6 in.)

Note: Above data for barehand application. For gloved hand operation, minima should be suitably adjusted.

FIGURE 4.4.7.5-1.   PUSHBUTTONS (FINGER OR HAND OPERATED)

there is no separation between alphabetic and numeric characters), or provide a separation to emphasize the two separate functions, with the numeric keyboard located to the right of the standard keyboard.

4.4.8.3 Dimensions, Resistance, Displacement, and Separation.

The control dimensions, resistance, displacement, and separation between adjacent edges of the push buttons, which form keyboards, should conform to the criteria in table 4.4.8.3-1. For a given keyboard, these criteria should be uniform for all individual keys.

4.4.8.4 Slope.

The slope of nonportable keyboards should be 260-435 mrad (15-25 degrees) from the horizontal. The preferred slope is 280-300 mrad (17-18 degrees). The slope of a portable device can be varied according to the preference of the operator.

4.4.8.5 Multiple Keyboards.

Systems containing more than one keyboard should maintain the same configuration for alphanumeric, numeric and special function keys throughout the system.

4.4.8.6 Feedback.

Feedback should be provided to inform the operator whether the intended key was pressed, and the next operation may be initiated, where applicable.

4.4.9 Toggle Switch Controls.

4.4.9.1 Use.

Toggle switches should be used for functions which require two discrete positions, or where space limitations are severe. Toggle switches with three positions should be used only where the use of a rotary control, legend switch control, etc., is not feasible, or where the toggle switch is of the spring-loaded, center position-OFF type. Three position toggle switches, which are spring-loaded to center-OFF from only one other position, should not be used if release from the spring-loaded position results in switch handle travel beyond the OFF position.

4.4.9.2 Accidental Actuation.

When the prevention of accidental actuation is of primary importance (i.e., critical, dangerous, or hazardous conditions would result), channel guards, lift-to-unlock switches, or other equivalent prevention mechanisms should be provided. Safety or

TABLE 4.4.8.3-1.   KEYBOARDS

| | Dimensions | | Resistance | | |
| | Diameter D* | | | | |
	Bare-handed	Arctic mittens**	Numeric	Alpha-numeric	Dual Function
Minimum	10 mm.	19 mm	1 N	250 mN	250 mN
Maximum	19 mm		4 N	1.5 N	1.5 N
Preferred	13 mm	19 mm			

| | Displacement | | | Separation |
	Numeric	Alpha-numeric	Dual Function	(between adjacent key tops)
Minimum	0.8 mm	1.3 mm	0.8 mm	6.4 mm
Maximum	4.8 mm	6.3 mm	4.8 mm	
Preferred				6.4 mm

*See Figure 4.4.7.5-1
**Trigger finger type

| | Dimensions | | Resistance | | |
| | Diameter D* | | | | |
	Bare-handed	Arctic mittens**	Numeric	Alpha-numeric	Dual Function
Minimum	0.385 in.	0.75 in.	3.5 oz	0.9 oz	0.9 oz
Maximum	0.75 in.		14.0 oz	5.3 oz	5.3 oz
Preferred	0.5 in.	0.75 in.			

| | Displacement | | | Separation |
	Numeric	Alpha-numeric	Dual Function	(between adjacent key tops)
Minimum	0.03 in.	0.05 in.	0.03 in.	0.25 in.
Maximum	0.19 in.	0.25 in.	0.19 in.	
Preferred				0.25 in.

*See Figure 4.4.7.5-1
**Trigger finger type

lock wires should not be used. Resistance of lift-to-unlock
mechanisms should not exceed 13 newtons (N) (3 pounds (lb)). If
a cover guard is used, its location, when open, should not
interfere with the operation of the protected device or adjacent
controls.

4.4.9.3 Dimensions, Resistance, Displacement, and Separation.

Dimensions, resistance, displacement, and separation between
adjacent edges of toggle switches should conform to the criteria
in figure 4.4.9.3-1. Resistance should gradually increase, then
drop when the switch snaps into position. The switch should not
be capable of being stopped between positions.

4.4.9.4 Positive Indication.

An indication of control activation should be provided (e.g.,
snap feel, audible click, associated or integral light).

4.4.9.5 Orientation.

Toggle switches should be vertically oriented with OFF in the
down position. Horizontal orientation and actuation of toggle
switches should be employed only for compatibility with the
controlled function or equipment location.

4.4.10 Legend Switches.

4.4.10.1 Dimensions, Resistance, Displacement, and Separation.

Dimensions, resistance, displacement, and separation between
adjacent edges of legend switches should conform to the criteria
in figure 4.4.10.1-1, except that maximum switch separation does
not apply to non-matrix applications.

4.4.10.2 Barrier Height.

Barrier height from panel surface should conform to the criteria
in figure 4.4.10.1-1. Unless otherwise specified, barriers are
required on critical switches, and on switches likely to be
inadvertently activated. Barriers, when used, should not obscure
visual access to controls, labels or displays, and should have
rounded edges.

4.4.10.3 Other Requirements.

   a. For positive indication of switch actuation, the legend
switch should be provided with a detent or click. When touch
sensitive switches are used, a positive indication of actuation
sho 'd be provided, e.g., an integral light within or above the
swi..h being actuated.

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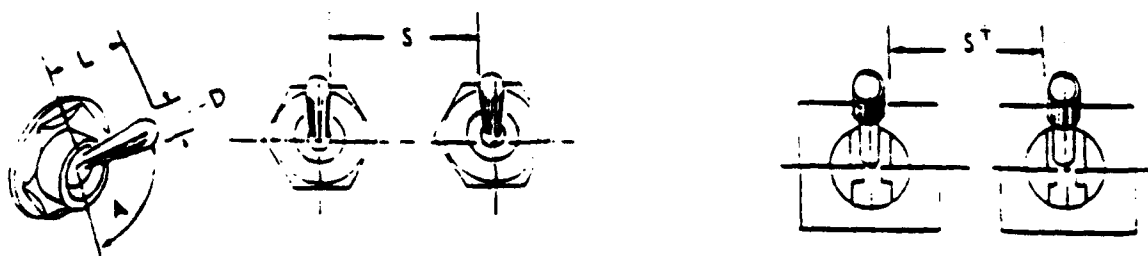
DIMENSIONS			RESISTANCE	
L Arm Length		**D** Control Tip	**Small Switch**	**Large Switch**
*	**			
Minimum				
13 mm (1/2 in.)	38 mm (1-1/2 in.)	3 mm (1/8 in.)	2.8 N (10 oz.)	2.8 N (10 oz.)
Maximum				
50 mm (2 in.)	50 mm (2 in.)	25 mm (1 in.)	4.5 N (16 oz.)	11 N (40 oz.)

DISPLACEMENT BETWEEN POSITIONS	
A	
2 Position	**3 Position**
Minimum 525 mrad (30°)	295 mrad (17°)
Maximum 1400 mrad (80°)	700 mrad (40°)
Desired ...	435 mrad (25°)

SEPARATION			
S			
Single Finger Operation		Single Finger Sequential Operation	Simultaneous Operation by Different Fingers
	†		
Minimum 19 mm (3/4 in.)	25 mm (1 in.)	13 mm (1/2 in.)	16 mm (5/8 in.)
Optimum 50 mm (2 in.)	50 mm (2 in.)	..~ mm (1 in.	19 mm (3/4 in.)

*Use by bare finger   **Use with heavy handwear   †Using a lever lock toggle switch

FIGURE 4.4.9.3-1.   TOGGLE SWITCHES

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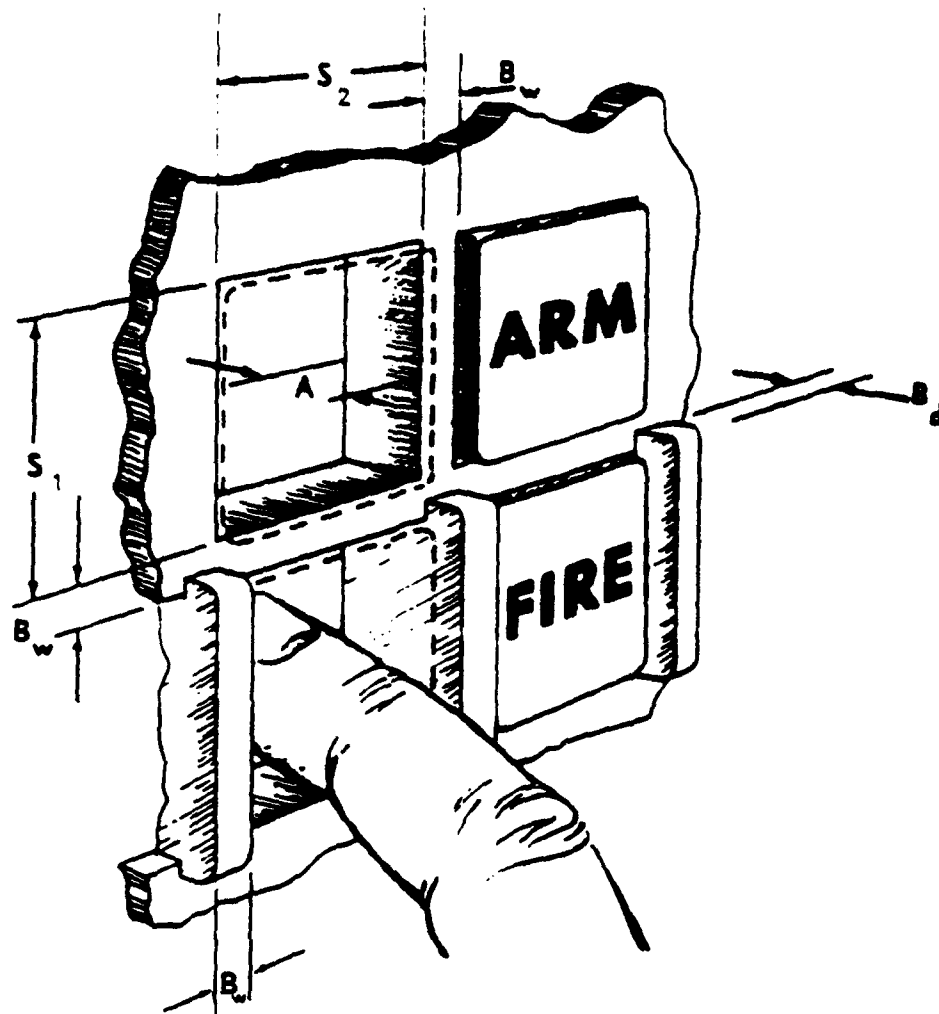
	S_1, S_2 Size	A DISPLACEMENT	BARRIERS		RESISTANCE
			B_w	B_d	
Minimum	19 mm * (3/4 in.)	3 mm ** (1/8 in.)	3 mm (1/8 in.)	5 mm (3/16 in.)	2.8 N*** (10 oz.)
Maximum	38 mm (1-1/2 in.)	6 mm (1/4 in.)	6 mm (1/4 in.)	6 mm (1/4 in.)	16.7 N (50 oz.)

* 15mm (5/8 in.) where switch is not depressed below the panel.

**5 mm (3/16 in.) for positive position switches.

***5.6 N (20 oz.) for use in moving vehicles.

NOTE: B_w also refers to switch separation.

FIGURE 4.4.10.1-1.   LEGEND SWITCH

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b. The legend should be legible with or without internal illumination.

c. A lamp test or dual lamp/filament should be provided for switches if the MTBF is less than 100,000 hours (hr).

d. Lamps within the legend switch should be replaceable from the front of the panel by hand, and the legends or covers should be keyed to prevent the possibility of interchanging the legend covers.

e. There should be a maximum of three lines of lettering on the legend plate.

4.4.11 Rocker Switches.

4.4.11.1 Use.

Rocker switches may be used in lieu of toggle switches for functions which require two discrete positions. They may be used for applications where toggle switch handle protrusions might snag the operator's sleeve or headset cord, or where there is insufficient panel space for separate labeling of switch positions. Rocker switches with three positions should be used only where the use of a rotary control, legend switch control, etc., i not feasible, or where the rocker switch is of the spring-loaded center-OFF type.

4.4.11.2 Accidental Actuation.

When the prevention of accidental actuation is of primary importance (i.e., critical, dangerous or hazardous conditions would result), channel guards or equivalent protective measures should be provided.

4.4.11.3 Positive Indication.

An indication of control actuation should be provided (e.g., snap feel, audible click, associated or integral light).

### 4.4.11.4 Dimensions, Resistance, Displacement and Separation.

Dimensions, resistance, displacement and separation between centers of rocker switches should conform to the criteria in figure 4.4.11.4-1. Resistance should gradually increase, then drop when the switch snaps into position. The switch should not be capable of being stopped between positions.
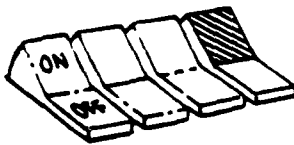
4.4.11.5 Orientation.

Where practicable, rocker switches should be vertically oriented. Actuation of the upper wing should turn the equipment or figure
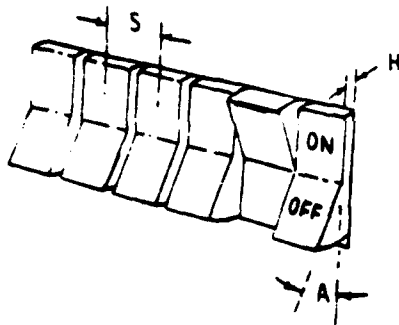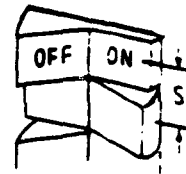
STANDARD ROCKER SWITCH:
USE AS ALTERNATE TWO-POSN
TOGGLE SWITCH TO PROVIDE
LABELING SURFACE, EASE OF
COLOR CODING, SWITCH
ILLUMINATION.
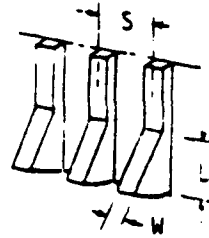
NARROW WIDTH, ESPECIALLY
DESIRABLE FOR TACTILE
DEFINITION WITH GLOVES.

ALTERNATE (CONTRAST) COLOR
FOR ON VERSUS OFF TO PROVIDE
CONSPICUOUS CUE OF SWITCH
POSITION. ILLUMINATED "ON"
DESIRABLE AS SECOND FEEDBACK
CUE.

| | DIMENSIONS | | RESISTANCE |
	W, WIDTH	L, LENGTH	
MINIMUM	6 mm (1/4")	13 mm (1/2")	2.8 N (10 oz.)
MAXIMUM			11 N (40 oz.)

| | DISPLACEMENT | | SEPARATION (Center-to-Center) | |
	H, HT, DEPRESSED	A, ANGLE	S (Bare Hand)	S (Gloved Hand)
MINIMUM	3 mm (1/8")	530 mrad (30°)	19 mm (3/4")	32 mm (1-1/4")

FIGURE 4.4.11.4-1.   ROCKER SWITCHES

component on, cause the quantity to increase, or cause the equipment or component to move forward, clockwise, to the right or up. Horizontal orientation of rocker switches should be employed only for compatibility with the controlled function or equipment location.

4.4.11.6 Color and Illumination.

Alternate colors may be used to denote the ON and OFF portions of a rocker switch. Alternate illumination of either the ON or OFF switch position may be used to facilitate positive recognition of current switch position. For areas where ambient illumination will provide display luminance below 3.5 cd/m^2 (1 Ft-L), the rocker switch should be internally illuminated. Digits and letters should appear as illuminated characters on an opaque background and their dimensions should approximate the following:

    a. Height: 4.8 mm (3/16").
    b. Height-to-Width Ratio: 3:2.
    c. Height-to-Stroke-Width Ratio: 10:1.

4.4.12 Slide Switch Controls.

4.4.12.1 Use.

Slide switch controls may be used for functions which require two discrete positions. Slide switch controls may also be used for functions which require a higher number of discrete positions in which the switches are arranged in a matrix to permit easy recognition of relative switch settings (e.g., audio settings across frequencies), but should not be used where mispositioning is to be avoided.

4.4.12.2 Accidental Actuation.

When the prevention of accidental actuation is of primary importance (i.e., critical, dangerous, or hazardous conditions would result), channel guards or other equivalent means should be provided.

4.4.12.3 Dimensions, Resistance, and Separation.

Dimensions, resistance, and separation of slide swi.ches should conform to criteria in figure 4.4.12.3-1. Detents should be provided for each control setting. Resistance should gradually increase, then drop when the switch snaps into position. The switch should not be capable of stopping between positions.

4.4.12.4 Orientation.

Where practicable, slide switches should be vertically oriented, with movement of the slide up or away from the operator, to turn
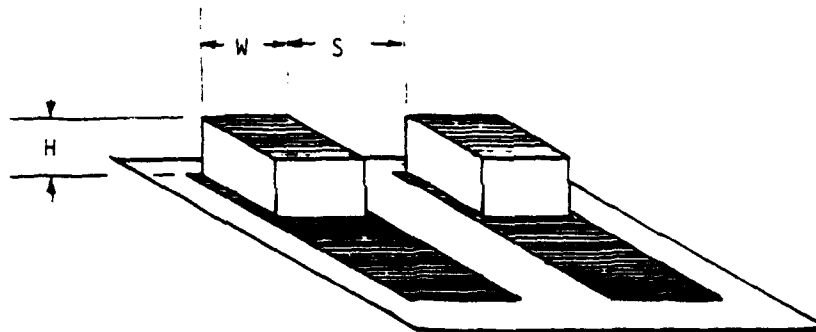
DIMENSIONS			RESISTANCE	
H ACTUATOR HEIGHT		W ACTUATOR WIDTH	SMALL SWITCH	LARGE SWITCH
*	**			
MINIMUM 6 mm (1/4").	13 mm (1/2")	6 mm (1/8")	2.8 N (10 oz.)	2.8 N (10 oz.)
MAXIMUM --	--	25 mm (1")	4.5 N (16 oz.)	11 N (40 oz.)

SEPARATION, S		
SINGLE FINGER OPERATION	SINGLE FINGER SEQUENTIAL OPERATION	SIMULTANEOUS OPERATION BY DIFFERENT FINGERS
MINIMUM 19 mm (3/4")	13 mm (1/2")	16 mm (5/8")
OPTIMUM 50 mm (2")	25 mm (1")	19 mm (3/4")

*Use by bare finger.
**Use with heavy handwear.

FIGURE 4.4.12.3-1.   SLIDE SWITCHES

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equipment on, increase a quantity, or move equipment forward, clockwise, to the right, or up. Horizontal orientation should be employed only for compatibility with the controlled function or equipment location.

4.4.12.5 Positive Indication.

Slide switch controls, involving more than two positions, should be designed to provide positive indication of control setting, preferably a pointer located on the left side of the slide handle.

4.4.13 Isometric Joystick (Two Axis Controllers).

Also known as stiff stick, force stick, or pressure stick, the isometric joystick control has no perceptible movement, but its output is a function of the force applied.

4.4.13.1 General Use.

Joystick controls may be used when the task requires precise or continuous control in two or more related dimensions. Isometric joysticks are particularly appropriate for applications: (1) which require precise return to center after each use, (2) in which operator feedback is primarily visual, rather than tactile feedback from the control itself, and (3) where there is minimal delay and tight coupling between control, input, and system reaction. Isometric sticks should ordinarily not be used in applications where it would be necessary for the operator to maintain a constant force on the control for a long period of time, or where there is no definitive feedback when maximum control inputs have been exceeded. Isometric joysticks may also be used for various display functions, such as data pickoff from a CRT. In rate control applications which may allow the follower (cursor or tracking symbol) to transit beyond the edge of the display, indicators should be provided in order to aid the operator in bringing the follower back onto the display.

4.4.13.2 Specific Use.

Thumbtip/fingertip operated joysticks may be mounted on a handgrip, which serves as a steady rest to reduce (dampen) vibrations or increase precision. If so mounted, the handgrip should not simultaneously function as a joystick controller.

4.4.14 Ball Control.

(Also known as track ball, ball tracker, joyball and rolling ball.)

4.4.14.1 Use.

A ball control suspended on low-friction bearings may be used for various control functions, such as data pickoff on a display. The ball control cannot provide an automatic return to point of origin, hence, if used in applications requiring automatic return to origin following an entry or readout, the interfacing system must provide this. Because the ball can be rotated without limit in any direction, it is well suited for applications where there may be accumulative travel in a given direction. In any application which would allow the ball to drive the follower on the display off the edge of the display, indicators should be provided to advise the operator how to bring the follower back onto the display. Ball controls should be used only as position controls (i.e., a given movement of a ball makes a proportional movement of the follower on the display).

4.4.14.2 Dynamic Characteristics.

The ball control should be capable of rotation in any direction so as to generate any combination of x and y output values. When moved in either the x or y directions alone, there should be no apparent cross-coupling (follower movement in the orthogonal direction). While manipulating the control, neither backlash nor cross-coupling should be apparent to the operator. Control ratios and dynamic features should meet the dual requirement of rapid gross positioning, and smooth, precise fine positioning.

4.4.14.3 Limb Support.

When trackball controls are used to make precise or continuous adjustments, wrist and/or arm support should be provided.
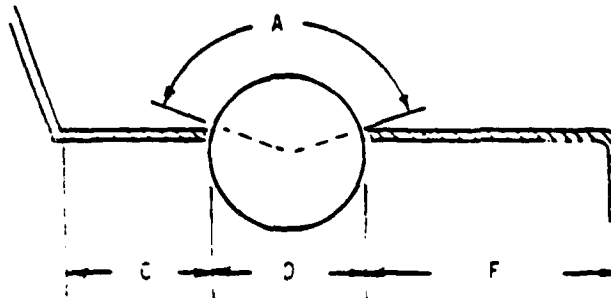
4.4.14.4 Dimensions, Resistance and Clearance.

Dimensions, resistance, and clearances should conform to the criteria in figure 4.4.14.4-1. The smaller diameter ball controls should be used only where space availability is very limited, and when there is no need for precision.

4.4.15 Touch-Screen Controls for Displays.

4.4.15.1 Use.

Touch-screen controls may be used to provide an overlaying control function to data displays where direct visual access, and optimum direct control access are desired.

	DIMENSIONS		RESISTANCE		CLEARANCE		
	D DIAM	A SURFACE EXPOSURE	PRECISION REQUIRED	VIBRATION OR ACCEL CONDITIONS	S DISPLAY CL TO BALL CL	C AROUND BALL	F FALL TO SHELF FRONT
MINIMUM	50 mm (2")	1545 mrad (100°)			0	50 mm (2")	120 mm (4-3/4")
MAXIMUM	150 mm (6")	2445 mrad (140°)	1.0 N (3.6 oz.)	1.7 N (6 oz.)	320 mm (12-5/8")		250 mm (9-3/4")
PREFERRED	100 mm (4")	2095 mrad (120°)	0.3 N (1.1 oz.)				

FIGURE 4.4.14.4-1.   BALL CONTROLS

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4.4.15.2 Luminance Transmission.

Touch-screen displays should have sufficient luminance transmission to allow the display, with touch-screen installed, to be clearly readable in the intended environment, and meet the display luminance requirements.

4.4.15.3 Positive Indication.

A positive indication of touch-screen actuation should be provided to acknowledge the system response to the control action.

4.4.15.4 Dimensions and Separation.

The dimensions and separation of responsive areas of the touch-screen should conform to S1, S2, and Bw of figure 4.4.10.1-1.

4.4.15.5 Resistance.

Force required to operate force-actuated touch-screens should conform to the alphanumeric resistance limits of table 4.4.8.3-1.

4.5 LABELING.

4.5.1 General Guidelines.

4.5.1.1 Application.

Labels, legends, placards, signs and/or markings should be provided, whenever necessary to identify, interpret, follow procedures or avoid hazards, except where it is obvious what an item is, and what to do with it.

4.5.1.2 Label Characteristics.

Label characteristics should be consistent with such factors as:

  a. Accuracy of identification required.
  b. Time available for recognition or other responses.
  c. Distance at which the labels must be read.
  d. Illuminant level and color.
  e. Criticality of the function labeled.
  f. Consistency of label design within and between systems.

4.5.1.3 Prototype and Production Equipment Labels.

Labels for both prototype and production equipment should meet the guidelines identified. Labels for production equipment should meet the criteria specified for the duration of equipment use. Since frequent design changes may be anticipated

in prototype equipment, labels for such equipment should be simply and easily affixed, altered, and removed.

4.5.2 Orientation and Location.

4.5.2.1 Orientation.

Labels and information should be oriented horizontally, so that they may be read quickly and easily from left to right. Vertical orientation may be used only when labels are not critical for personnel safety or performance, and where space is limited. When used, vertical labels should read from top to bottom.

4.5.2.2 Location.

Labels should be placed on or very near the items which they identify, so as to eliminate confusion with other items and labels. Labels should be located so they do not obscure any other information needed by the operator. Controls should not obscure labels.

4.5.2.3 Standardization.

Labels should be located in a consistent manner throughout the equipment and system.

4.5.3 Contents.

4.5.3.1 Equipment Functions.

Labels should primarily describe the functions of equipment items. Engineering characteristics or nomenclature may be described as a secondary consideration.

4.5.3.2 Abbreviations.

Standard abbreviations should conform to MIL-STD-12, MIL-STD-441, or MIL-STD-783. If a new abbreviation is required, its meaning should be obvious to the intended reader. Capital letters should be used, and periods should be omitted, except when needed to preclude misinterpretation. The same abbreviation should be used for all tenses, and for both singular and plural forms of a word.

4.5.3.3 Irrelevant Information.

Trade names and other irrelevant information should not appear on labels or placards.

4.5.4 Label Qualities.

4.5.4.1 Brevity.

Labels should be as concise as possible without distorting the intended meaning or information, and should be unambiguous. Redundancy should be minimized. Where the general function is obvious, only the specific function should be identified (e.g., frequency, as opposed to frequency factor).

4.5.4.2 Familiarity.

Words should be chosen on the basis of operator familiarity whenever possible, provided the words express exactly what is intended. Brevity should not be stressed if the results will be unfamiliar to operating personnel. For particular users (e.g., maintenance technicians), common technical terms may be used even though they may be unfamiliar to nonusers. Abstract symbols (e.g., squares and Greek letters) should be used only when they have an accepted meaning to all intended readers. Common, meaningful symbols (e.g., % and +) may be used, as necessary.

4.5.4.3 Visibility and Legibility.

Labels and placards should be designed to be read easily and accurately at the anticipated operational reading distances, and in the anticipated vibration/motion environment and levels of illumination.

4.5.4.4 Access.

Labels should not be covered or obscured by other units in the equipment assembly.

4.5.4.5 Label Life.

Labels should be clear and distinct, have high contrast, be mounted so as to minimize wear or obscurement by grime, and remain legible for the overhaul interval of the equipment on which they are mounted.

4.5.4.6 Label Background.

Label color should contrast with the equipment background. No special background for the label should be provided without approval by the procuring activity.

4.5.5 Design of Label Characters.

4.5.5.1 Black Characters.

Where the ambient illuminance will be above 10 lux (0.9 ft-c), black characters should be provided on a light background.

4.5.5.2 Dark Adaptation.

Where dark adaptation is required, the displayed letters or numerals should be visible without interfering with night vision requirements. Where possible, markings should be white on a dark background.

4.5.5.3 Style.

Style of label characters should conform to MIL-M-18012, consistent with sections 4.5.5.4, 4.5.5.5, 4.5.5.7, and 4.5.5.8.

4.5.5.4 Capital vs Lower Case.

4.5.5.4.1 Labels.

Labels should be printed in all capitals; periods should not be used after abbreviations.

4.5.5.4.2 Legends.

Legends should be printed in all capitals; periods or commas should not be used.

4.5.5.4.3 Placards.

Instructional material placards may employ capitals and lower case when the amount of material consists of several lines; however, for short, instructional material, all capitals are preferred. All capital material, consisting of large initial letter in a paragraph, line of instruction, or procedural step, may be used.

4.5.5.4.4 Signs.

Signs should consist of all capitals, except when the sign is instructional and involves several lines of extended sentences, in which case capitals and lower case letters may be used.

4.5.5.5 Letter Width.

The width of letters should be 3/5 of the height, except for "M" and "W", which should be 4/5 of the height, and "I", which should be one stroke wide.

4.5.5.6 Numeral Width.

The width of numerals should preferably be 3/5 of the height, except for the "4", which should be one stroke width wider, and the "1" which should be one stroke wide.

4.5.5.7 Wide Characters.

Where conditions indicate the use of wider characters, as on a curved surface, or where numerals must be aligned vertically in columns, the basic height-to-width ratio may be increased to as much as 1:1.

4.5.5.8 Stroke Width Normal.

For black characters on a white (or light) background, the stroke width should be 1/6 to 1/7 of the height.

4.5.5.9 Stroke Width, Dark Adaptation.

Where dark adaptation is required, or legibility at night is a critical factor, and white characters are specified on a black background, the stroke width of the characters should be from 1/7 to 1/8 of the height (i.e., narrower than specified for normal daytime vision). The stroke width should be the same for all letters and numerals of equal height.

4.5.5.10 Stroke Width, Transilluminated Characters.

For transilluminated characters, the stroke width should be 1/10 of the height.

4.5.5.11 Character Spacing.

The minimum space between characters should be one stroke width.

4.5.5.12 Word Spacing.

The minimum space between words should be the width of one character.

4.5.5.13 Line Spacing.

The minimum space between lines should be one-half character height.

4.5.5.14 Label Size vs Luminance.

The height of letters and numerals should be determined by the required reading distance and luminance. With a 710 mm (28 in)

viewing distance, the height of numerals and letters should be within the range of values in table 4.5.5.14-1 for "low" and "high" control-display luminance conditions.

TABLE 4.5.5.14.1 LABEL SIZE VERSUS LUMINANCE

MARKINGS	HEIGHT*	
	3.5 cd/m^2 (1 ft-L) OR BELOW	ABOVE 3.5 cd/m^2 (1 ft-L)
For critical markings, with position variable (e.g., numerals on counters and settable or moving scales):	5 - 8 mm (0.20-0.31 in.)	3 - 5 mm (0.12-0.20 in.)
For critical markings, with position fixed (e.g., numerals on fixed scales, controls, and switch markings, or emergency instructions):	4 - 8 mm (0.16-0.31 in.)	2.5 - 5 mm (0.10-0.20 in.)
For noncritical markings (e.g., identification labels, routine instructions, or markings required only for familiarization):	1.3 - 5 mm (0.05-0.20 in.)	1.3 - 5 mm (0.05-0.20 in.)

*Values assume a 710 mm (28 in.) viewing distance. For a distance, D, other than 710 mm (28 in.), multiply the above values by D/710 mm (D/28 in.).

4.5.5.15 Character Height and Viewing Distance.

For general dial and panel design, with the luminance normally above 3.5 cd/m^2 (1 ft-L), character height should conform to the values given below for various distances:

Viewing distance	Minimum height
less than 500 mm (19.7 in)	2.3 mm (0.09 in)
0.5 - 1.0 m (19.7 - 39.4 in)	4.7 mm (0.18 in)
1.0 - 2.0 m (39.4 - 78.7 in)	9.4 mm (0.37 in)
2.0 - 4.0 m (78.7 - 157.5 in)	19 mm (0.75 in)
4.0 - 8.0 m (157.4 - 315.5 in)	38 mm (1.50 in)

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4.5.6 Equipment Labeling.

4.5.6.1 Units, Assemblies, Subassemblies and Parts.

4.5.6.1.1 General Guidelines.

Each unit, assembly, subassembly, and part should be labeled with a clearly visible, legible, and meaningful name, number, code, mark or symbol, as applicable.

4.5.6.1.2 Location.

The gross identifying label on a unit, assembly or major subassembly, should be located:

 a. Externally in such a position that it is not obscured by adjacent items.

 b. On the flatest, most uncluttered surface available.

 c. On a main chassis of the equipment.

 d. In a way to minimize wear or obscurement by grease, grime, or dirt.

 e. In a way to preclude accidental removal, obstruction, or handling damage.

4.5.6.1.3 Terms.

Equipment should be labeled with terms descriptive of the test or measurement applicable to their test points (e.g., demodulator rather than crystal detector, and power amplifier rather than bootstrap amplifier).

4.5.6.1.4 Other Guidelines.

In addition to the guidelines herein, equipment labels and placards should conform to MIL-STD-129, MIL-STD-130, MIL-STD-195, MIL-STD-411, MIL-STD-783, MIL-STD-1247, and Requirement 67 of MIL-STD-454, as applicable.

4.5.6.2 Controls and Displays.

4.5.6.2.1 General Guidelines.

Controls and displays should be appropriately and clearly labeled with the basic information needed for proper identification, utilization, actuation, or manipulation of the element. Integrally illuminated panels should comply with FAA regulations.

4.5.6.2.2 Simplicity.

Control and display labels should convey verbal meaning in the most direct manner, by using simple words and phrases. Abbreviations may be used when they are familiar to operators (e.g., psi, km).

4.5.6.2.3 Functional Labeling.

Each control and display should be labeled according to function, and the following criteria should apply:

a. Similar names for different controls and displays should be avoided.

b. Instruments should be labeled in terms of what is being measured or controlled, taking into account the user and purpose.

c. Control labeling should indicate the functional result of control movement (e.g., increase, ON, OFF) and may include calibration data where applicable. Such information should be visible during normal operation of the control.

d. When controls and displays must be used together (in certain adjustment tasks), appropriate labels should indicate their functional relationship.

e. The selection and use of terminology should be consistent.

4.5.6.2.4 Location.

The following guidelines should apply to the location of control and display labels:

a. Ease of control operation should be given priority over visibility of control position labels.

b. Labels should normally be placed above the controls and displays they describe. When the panel is above eye level, labels may be located below, if label visibility will be enhanced.

c. The units of measurement (e.g., volts, psi, meters) should be labeled on the panel.

d. Labels should be used to identify functionally-grouped controls and displays. The labels should be located above the functional groups they identify. When a line is used to enclose a functional group and define its boundaries, the label should be

centered at the top of the group, either in a break in the line or just below the line. When colored pads are used, the label should be centered at the top within the pad area.

    e. Label location throughout a system, and within panel groupings, should be uniform.

4.5.6.2.5 Size Graduation.

To reduce confusion and operator search time, labels should be graduated in size. The characters in group labels should be larger than those used to identify individual controls and displays. The characters identifying controls and displays should be larger than the characters identifying control positions. With the smallest characters determined by viewing conditions, the dimensions of each character should be at least 25 percent larger than those of the next smaller label.

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MIL-STD-1472, <u>Human Engineering Design Criteria for Military Systems, Equipment and Facilities</u>, March 1989.

Smith, S. L., and Mosier, J. N., <u>Guidelines for Designing User Interface Software</u>, Electronic Systems Division, AFSC, Hanscom AFB, MA, ESD-TR-86-278, August 1986.

APPENDIX A

SAMPLE OF CHECKLIST

CHECKLIST ITEM	COMMENTS	COMPLIANCE	
		WGHT	YES
4.4.7 PUSHBUTTONS			
SIZE 1. Button size is at least 1/2 inch diameter.		1	
2. For the special case of thumb or heel of hand operation, the button size is at least 3/4 inch diameter.		1	
SPACING 3. Spacing between edges of adjacent p/b controls designed for fingertip operation (e.g., on keyboards, keysets, special purpose matrices) is at least 1/4 inch.		1	
4. Spacing between edges of individual p/b's is at least 3/8 inch.		1	
5. For the special case of thumb or heel of hand operated p/b, spacing between edges of adjacent controls is at least 2 inches.		1	
DISPLACEMENT 6. For multiple operation (e.g., on keyboards, keysets, or special purpose matrices) the displacement of all p/b in the matrix is constant and within		2	